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# AUGUST

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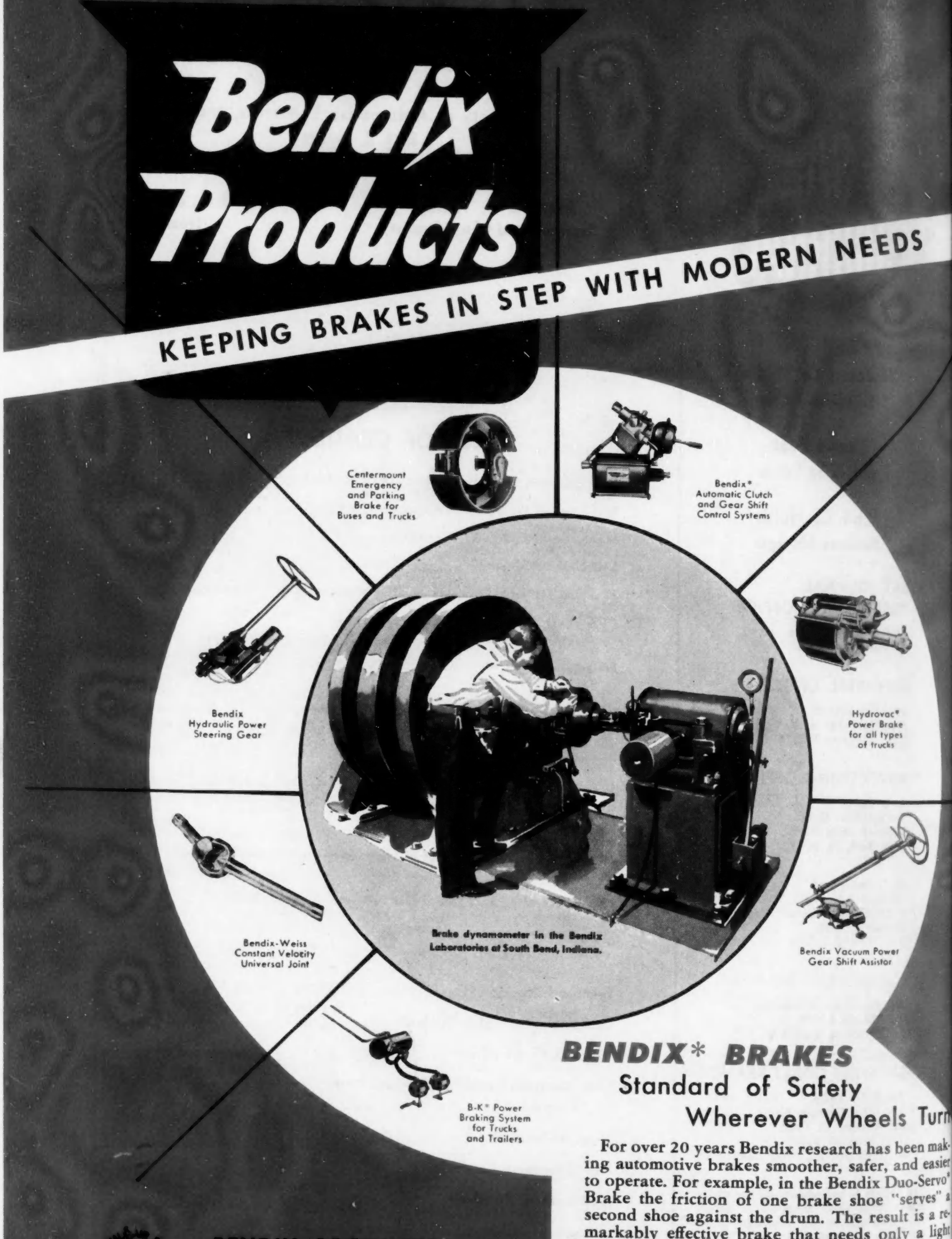

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# WHAT'S COMING In Fuels and Oils?

EXCERPTS FROM PAPER* BY
**R. J. S. Pigott** Chief Engineer
Gulf Research & Development Co.

Gains in wartime fuel and lubricant developments and their influence on engine design are reported in this roundup article by SAE President Pigott.

He surveys prospects of higher octane gasolines, synthetic lubricants, fuel injection, and new bearing materials. On these and other petroleum and engine advances, frank analysis backed up with engineering facts of life support his forecasts.

WE are all aware that research ought to be most actively pursued during times of least stress; but human beings are illogical, and the most rapid developments usually occur under pressure during a war. As a consequence the picture on fuels and lubricants, and on design ideas, was considerably changed during the late unpleasantness.

FUELS

Octane value of gasolines, to serve higher compression ratio engines, has been pushed tremendously for some years and charts have frequently been published showing that all the gain in horsepower has been due to octane rating. Many have thought that because 100 octane gasoline (and higher) had to be made for war planes, we should be using 100 octane in passenger cars shortly. This foolish idea needs deflating.

In the first place, 100 octane gasoline for general use would cut the total production considerably, by present refining methods. This we could not possibly afford; but we can do something shortly without sacrificing output. There are now engines designed that would be satisfactory for passenger service at compression ratios of 7.5 or 8 to 1, which will require something like 88 to possibly 93 Research Method octane number. The designers have now controlled roughness simply by making the engine structure sufficiently rigid.

Preignition has hitherto shown up pronouncedly as compression ratio increases, in ordinary designs faked up to 8.5 to 1, but seems to be under satisfactory control in the new designs.

These new designs show gains in economy of possibly 25% at 8 to 1, 40% at 12.5 to 1. These gains considerably exceed the

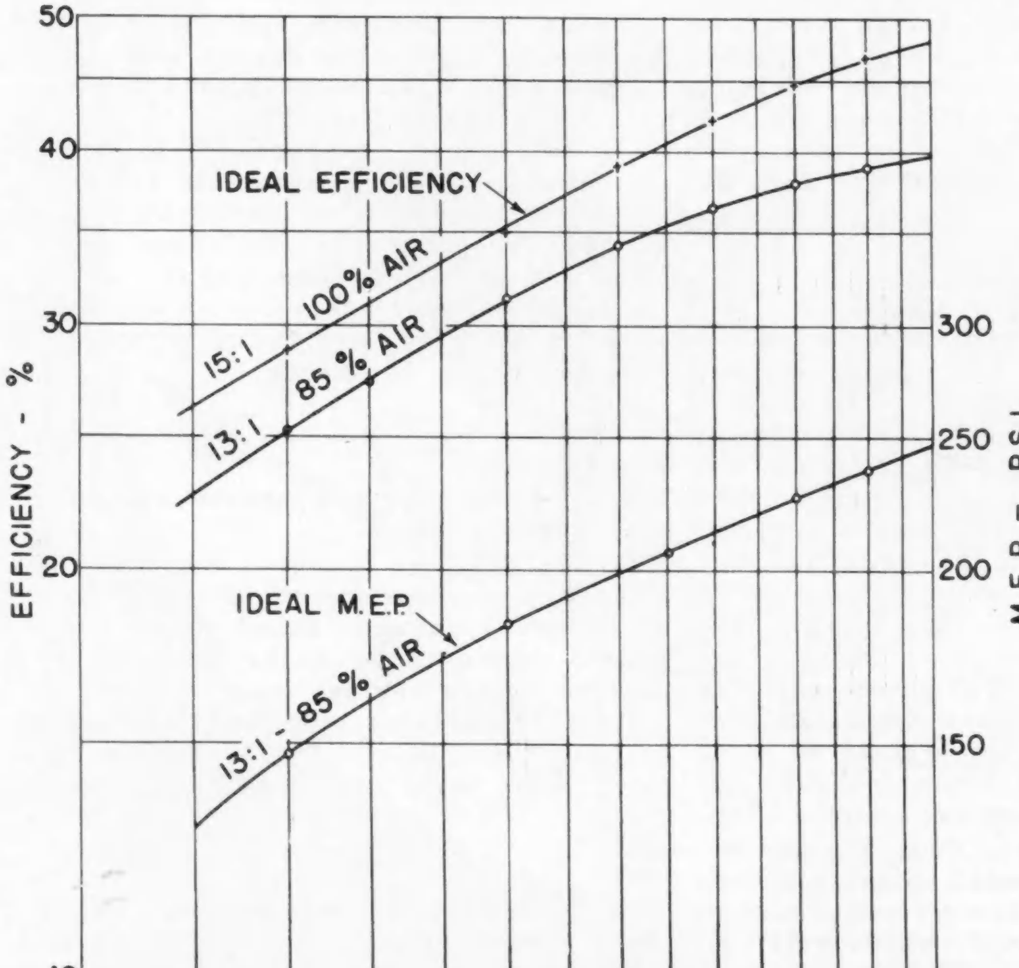
*Paper "Developments in Fuels, Lubricants, and Lubrication," was presented during March and April, 1948 at the following SAE Sections: Western Michigan, Baltimore, Virginia, Syracuse, and Buffalo.

cycle gain in efficiency (see Fig. 1) and are due to subsidiary effects. Since no appreciable increase in power is contemplated, the higher compression ratio produces higher bmep and permits a proportionally smaller engine. It cuts breathing and mechanical losses and raises mechanical efficiency. This gain is added to the cyclic efficiency gain.

Further, lower dilution with products of combustion raises part-throttle efficiency. So we need not be too surprised that the actual gain exceeds the cyclical. We already know that only 20% of the horsepower increase in the period 1930 to date has been from compression ratio; the rest is due to larger size, higher revolutions per minute, better breathing and manifolding, and other design improvements.

We probably will not get all of the gains indicated above in actual road performance, but perhaps 80% of them. Much of the improvement in lowered octane demand of the engine is due purely to design—principally better and more uniform cooling.

Thus the general view is that there will be a moderate rate of increase in compression ratio and octane rating for the next two or three years, tuned to the ability of the petroleum industry to supply the right fuel. The octane ratings now used are based on the Research Method, a CFR rating, and are from 6 to 10 numbers higher than the Motor Method, or ASTM rating formerly employed. Before the war, the best premium gasoline was 81-83 Motor Method. Since the war, the Motor Method ratings have not changed significantly, but the sensitivity of the fuels has increased and the best products now have Research ratings of 89-93 octane range. So by the mere substitution of one test




●Fig. 1 - Change in full throttle efficiency and mean effective pressure with increase in compression ratio

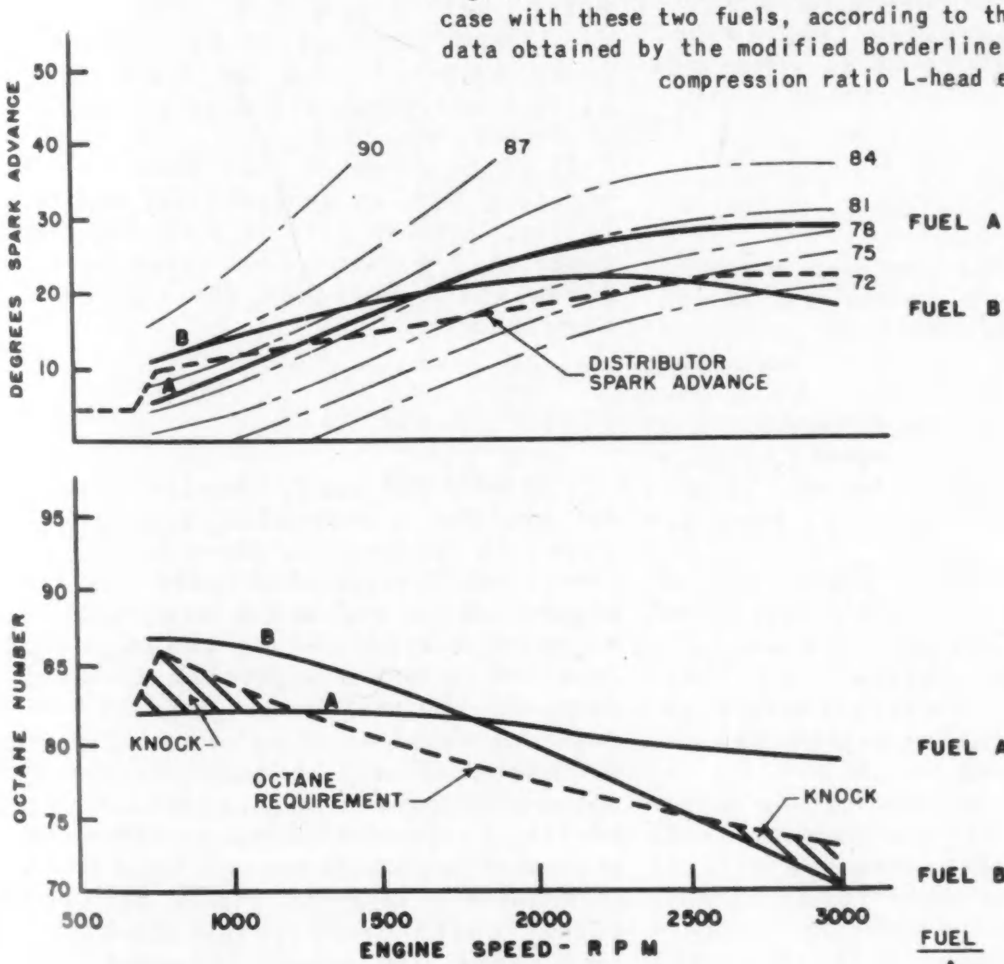
method for another, most of the skip toward 100 octane has been accomplished. Consensus of opinion collected by A. T. Colwell was that 8 to 1 would likely be the highest compression ratio for a year or two.

What is at present the most interesting and valuable improvement now going on is tailoring the gasoline to suit the engine. It is now known that a single octane number does not fully define the quality of gasoline since the engine octane demand varies with speed. Therefore, of two gasolines of identical octane number by any one method, one may be knock-free at high speed, not at low; the other the reverse. We now run road ratings at speeds from 10 to 70 mph and get the characteristic octane rating of the gasoline with speed. When this has been done, the single standard test octane number is an adequate criterion of the general level of the octane value for control purposes. Fig. 2 shows a typical curve.

Other much less publicized qualities of gasoline are important. Volatility determines the engine behavior considerably, and has almost as much influence on driver good temper as octane value. The 10% evaporation temperature generally accounts for ease of starting; the 50% point for quick warm-up; the 90% point, to a lesser degree for warm-up and engine fouling deposits. Gasolines actually have been on the market, that started instantly in cold weather; but the engine immediately died and several starts were necessary. This means 10% point O.K., 50% point too high. The reverse has also been true. Fig. 3 shows the general range.

It is plain that the refiner has a rather difficult task in many cases since he has been chiefly refining to get high-

● Fig. 2 - Gasoline octane number may vary with speed. This is the case with these two fuels, according to the charted road octane data obtained by the modified Borderline Method in a 6.8 to 1 compression ratio L-head engine




LABORATORY RATINGS

| FUEL | ASTM | RESEARCH |
|---|---|---|
| A | 79.0 | 87.0 |
| B | 79.2 | 90.5 |

er octane value. But he must simultaneously control volatility, and the two do not always travel together in refining. So a compromise must be adopted, always keeping cost of manufacture in mind.

The use of tetraethyl lead has always been justified, since it has been up to the present the cheapest method of getting octane rating. But the lead susceptibility of gasolines is such that increasing amounts of lead produce less and less improvement in octane value.

As matters stand, we have gasolines that are ample in octane value for all the present cars, new and old, and they are improving in volatility characteristics and stability.

The old argument of carburetion versus injection still goes on, without about the same conclusions. Injection can get rid of most distribution troubles (air distribution can cause some of the difficulties), which are usually present in carburetor plus manifold combinations. Injection means leaner average mixture, lower octane requirement, and better economy; theoretically, that is not, however, always attained in commercial use.

## INJECTOR PROBLEMS

The main obstacles are cost and maintenance, the injector system must be precision made and is therefore quite vulnerable to poor lubrication and dirt; diesel injector experience is a good proof. But the major item by far is first cost. Until the injector system is about as cheap as a carburetor system, it will not see much application to gasoline engines.

Diesel fuels and fuel oils have been, in general, a byproduct of gasoline refining. Since "cat" cracking is considerably employed, we must accept "cat-cracked" material in these fuels also, and the advantages and disadvantages are of much the same kind.

The advantage is higher Btu per gallon and there may easily be advantages in ignitability. The disadvantage will be due chiefly to lower stability in blends, and has given rise to deposits in storage tanks and clogged filters in the earlier blends brought out. Some trouble also can be seen in deposits on the burner and boiler, but it should be stressed that "cat-cracked" materials do not need to be any less stable than straight-run stock.

The refining operation can be readjusted to make highly stable fractions, and some of the latest fuel oil blends containing 50% "cat-cracked" material show as good burner performance as 100% straight-run. All of these conditions had to be found, as little or nothing was known of the peculiarities of "cat-cracked" stock when it was first produced. Many hundred thousand dollars have been spent in research on the new fuel oils since V-J Day.

In all probability we shall find that much the same properties required to make a diesel fuel good are required for a fuel oil. We are beginning to establish correlations between cold starting and smoke. And such criteria of diesel fuel as specific gravity, cetane number, cetane index, diesel index, aniline point, acid absorption, acid flocculation, and the English test for smoke-point may be of value for the performance of fuel oil. Carbon-hydrogen correlation also looks promising.

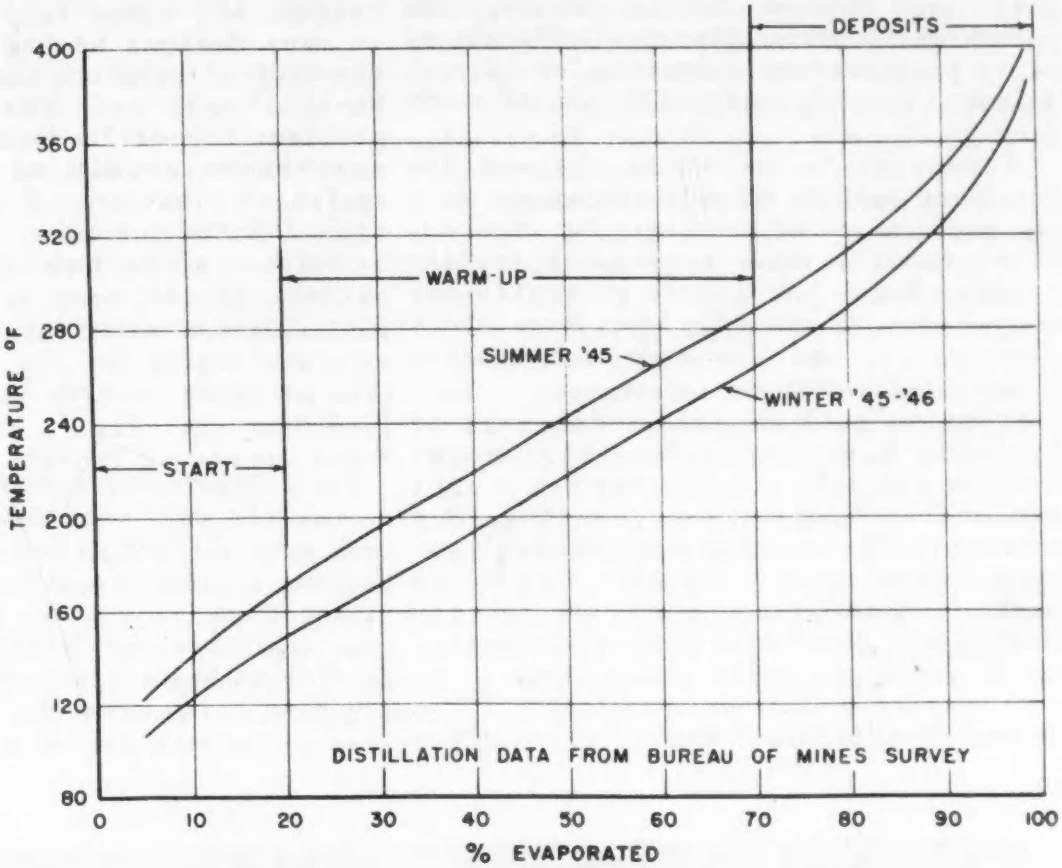
It is to be noted that there is a distinction between ignitability and burnability. Ignitability is probably chiefly controlled by front end volatility, but burnability involves the character of combustion.

## "CAT" OIL DEPOSITS

Straight-run oils, chiefly paraffinic and naphthenic molecules, appear to burn directly to carbon dioxide and water vapor; but "cat-cracked" oils, containing high olefins and aromatics, appear to burn by a kind of two-stage process. First there occurs a partial oxidation of some of the material to resinous or gummy material—a kind of cracking with oxidation. These intermediate compounds appear to have a high ignition point; and if the furnace parts or refractories are not hot enough to ignite them, they will deposit as gum or resin, fouling the burner parts or shorting the starting electrodes. The second stage of combustion extends, so to speak, from the first

when these byproducts are in turn ignited.

The rotary wall flame-type of burner is somewhat more sensitive to these fuels as there is an area which is hot and in which no combustion occurs. It is between the fan (where oil and air enter the combustion chamber) and the point of flame-production. This space is not hot enough to complete the combustion of the gummy byproducts, but is hot enough to cause their formation.




●Fig. 3 - Typical distillation data for a premium grade fuel

Gun type burners, which complete the combustion in a refractory chamber right at the point of entry, are not appreciably sensitive to these fuels. The combustion chamber is very hot, combustion is largely completed before much heat absorption occurs, and the flame is within a few inches of the atomizer nozzle. This fortunate condition should not be taken to mean the gun types are generally superior to the rotary wall flame types; they have other troubles.

It must be recognized that, in general, the design of a bearing has much more controlling influence on successful operation than any oil that may be used in it. The proof was plain in the early days of this century when bearings were more generally lower load and speed. For example, reciprocating engines and compressors and later the steam turbine, with bearing loads under 200 psi, ran very well on oils we should now consider quite inferior. The oil remained in use for periods of three to five years, prime movers in many cases operating a total of 30,000 hr before oil change.

In the modern steam turbine today we have very moderate inlet and bearing temperatures, not often above 200F, substantially no contamination, continuous filtration and centrifuging. In this case the use of oxidation inhibitors has greatly increased the oxidation life of the oil. But the internal combustion engine brought in much more trying conditions. Much higher temperatures are prevalent, from a crankcase temperature of 240F to 280F up to piston temperatures

of 400F or more. Moreover, some of the oil on the cylinder wall is subjected to flame temperature, and all of it is exposed to combustion byproducts.

Bearing in mind that chemical rate of breakdown doubles every 20-degree rise in operating temperature, the usual safe life of 60 to 100 hr in automotive engines is not too surprising. Contributing to the deterioration is the contamination from gum and water containing sulfur compounds. These come from the fuel. Road dirt, even through the air cleaner, adds to the difficulties of proper lubrication, as it promotes rapid destruction of conditioned rubbing surfaces by way of scuffing.

A year or so prior to the war, we developed methods of calculating not only the performance of bearings, but the performance of a whole engine lubricating system. Since the oil is generally the chief means of removing heat from lubricated parts, the flow over each bearing is obviously of major importance.

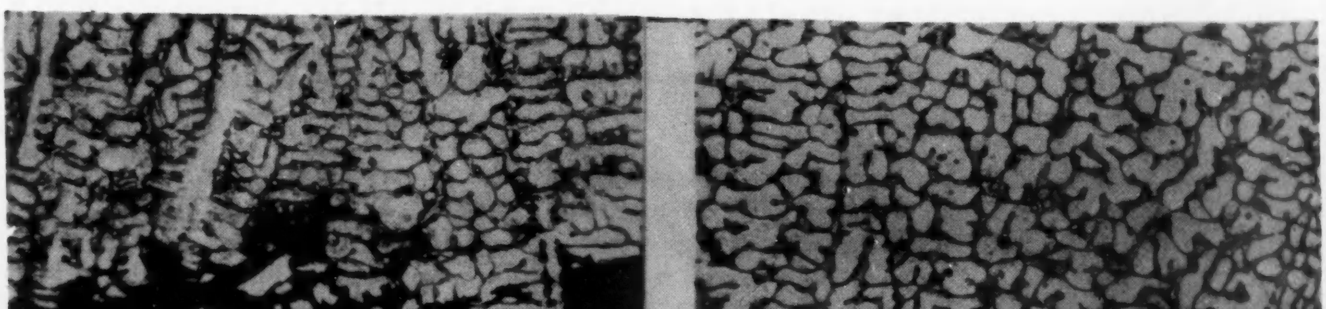
Starting with Reynolds, the work of Michell, Kingsbury, Howarth, Needs, Denison and others has permitted a fair rational calculation of bearing load capacity. The cooling requirement mentioned above is not the only reason for controlled and known flow - the bearing conditions, particularly mean viscosity, are also directly affected by flow.

We have been able to compute the flows to each bearing in 8 and 12-cyl engines within 5% of the measured flow in operation. By this means we have found and corrected the cause of puzzling bearing failures. Such a method is an exceedingly valuable tool in design, to avoid costly corrections afterward.

## CORROSION PROBLEM RECENT

When babbitt was the major bearing material, we never heard of bearing corrosion, but since loads have increased in many designs beyond the fatigue resistance of babbitt, the newer materials have brought with them the corrosion problem. Copper-lead and cadmium-silver are two materials of higher fatigue resistance, but are very subject to corrosion. Since corrosion is largely caused by organic acids developed in the oil by oxidation, the cure is in the form of antioxidation additives. These compounded oils are available. Fig. 4 shows the action of organic acids on lead in copper-lead bearings. Fig. 5 shows initial and final stages of fatigue failure.

The 2-104B oils, developed for Army use during the war, were designed to work in both gasoline and diesel engines to avoid bearing corrosion and to keep the engine clean. These oils, containing both corrosion inhibitor and detergent, proved successful in keeping the engine - especially the ring belt - cleaner; and they are now used commercially for severe truck and



●Fig. 4 - The gray structure, lead, in this uncorroded copper-lead bearing at left extends to the bearing surface. The corroded bearing at right has large voids where lead has been removed

bus service, being known as heavy-duty oils. Generally they will not cure deposits caused by the fuel or winter sludge; no oil at present will do much to these kinds of deposits.

For lighter commercial truck service or passenger car operation a mild inhibited class of oil is preferred, known as "premium." The designers in their effort for more performance from smaller, lighter engines may raise the severity of passenger car engines in the next few years so that they need more highly-compounded oil.

Silver bearings have become prominent through the aviation industry. This material has the highest fatigue strength of any, and is as corrosion-free as high-tin babbitt. In other respects silver is not good, having low conformability and embeddability and poor seizure characteristics when dirt is present. But an overplate of lead or lead-indium converts it into a satisfactory bearing, very suitable for high load service.

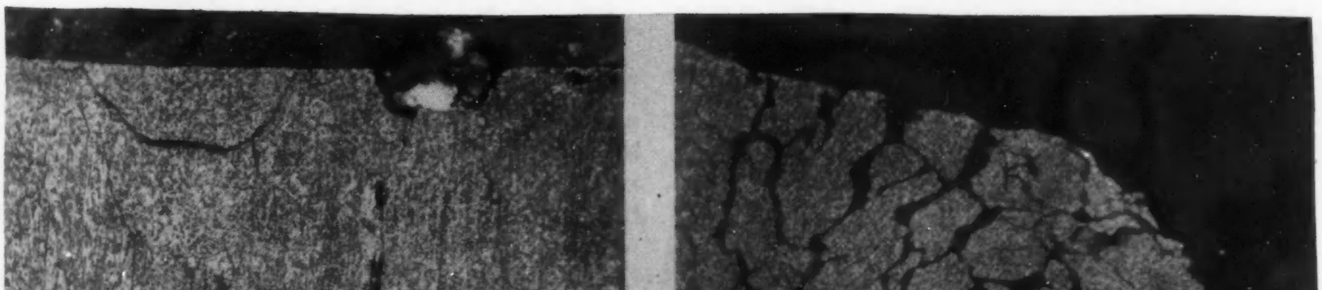
## ALUMINUM BEARINGS EMERGING

We probably shall see a considerable increase in use of aluminum alloy bearings, since these have high fatigue strength, better than copper-lead, and appear to be short only on embeddability. Investigated by Rolls-Royce after World War I, these alloys have been subject to considerable research and offer a very desirable group of qualities. Since tin will not be readily available for years, the high-lead babbitts are likely to replace high-tin babbitt permanently for those bearings requiring only low fatigue strength. Aluminum alloys have a chance to replace copper-lead and cadmium alloys.

In hydrodynamic, or perfect film lubrication, the two important physical properties are viscosity and specific heat. The specific heat is of interest for cooling; but since its value varies only from about 0.50 to 0.55 in all lubricating oils, there is no point in using it as a criterion of value. Cooling must be provided by quantity of flow through the bearing.

From consideration of the formulas for load capacity, it would be very useful if we could find a liquid with a viscosity that does not vary with temperature. No such liquid suitable for lubrication is known to exist, and none is likely to be found. But the variation of viscosity with temperature, specified arbitrarily by viscosity index, has been improved of late years. We still have plenty of oils, with V.I.'s of 30 to 65, but all the better grade oils are up around 95 to 105. For cases where temperature variation in operation is wide, these oils are desirable. For example, viscosity variation —even with these high grade oils—is 40 to 1 between room temperature and crankcase temperature.

Many oils are now made with viscosity



•Fig. 5 - Fatigue breakdown has started in the uncorroded main bearing shell, photomicrographed at left. The right-hand photomicrograph shows complete fatigue failure in a bearing from the same engine

index improvers, but sometimes the experience with them is disappointing. Cases have been noted with severe duty and agitation, as in the recoil cylinder of a gun, where the additive molecules break down and the viscosity index improvement is lost.

The new synthetics can be made of very high V.I., 150 and better, and these doubtless will be employed to improve petroleum oil viscosity index and solvent power. The cost is at present about two to three times that of high grade petroleum oils. Therefore, until this situation is improved, we shall not see much synthetic oil in use, except for moderate blends, in aviation hydraulic systems where temperature varies from -60 to +150F, and where cost is not important.

Corrosion of copper-lead and cadmium alloy bearings has been eliminated by the use of oxidation inhibitors. Where temperatures are not severe, ordinary uncompounded oils will work, but in general the corrodible bearing alloys are used in relatively severe duty and need the compounded oils.

Detergency is desirable for diesel ring belts and for general engine cleanliness in both heavy duty gasoline and diesel engines. This property should be desirable for aviation engines, although the Armed Forces have consistently refused compounded oils for aviation up to now. Detergency agents will not have much effect on deposits caused by gasoline or on winter sludge. However, it must be said that some of the additives used, while keeping the engine cleaner, have shown some tendency to increase combustion chamber deposits and foul plugs.

## FOAM SUPPRESSED

Foaming of lubricating oils is not materially different for any normal oil. But in general the additives, especially the detergent group, increase foaming. A valuable antifoam agent was developed and is now rather generally used. It is employed in very small concentration, 0.01% or less, and completely suppresses foam at a free surface. But it is certainly not a panacea as it can do little about entrained air bubbles, submerged in oil.

The cause of foaming is improper design, and it is much better to prevent the formation of foam than to break it after it is formed. Many combat vehicle cases, particularly gear boxes and lube oil tanks, with no opportunity to improve the design, were taken off the sick list by this antifoam agent.

## GEAR OIL PROGRESS

Gear oils have not changed much, but the lighter 75 gear oil developed for Army Arctic service worked out well. Before the war the use of much lighter gear oils (SAE 10 and 20) was investigated; present results indicate that it may be possible to substitute these light oils for the heavier material, possibly with the use of additives of an E.P. nature similar to hypoid lubricants. The reward is noticeable in high speed gears, where lubricant pumping losses and heat developed may be excessively high with viscous oil.

Summing up, the war-forced developments have been good, but not startling. No miraculous changes have taken place or are expected, but the advance of quality and performance has been accelerated. Probably the major development, other than atomic fission, is that of the commercial production of the gas turbine.

It is interesting to reflect on the possibility that if the gas turbine largely replaces the reciprocating engine, the need for high octane gasoline would disappear. The gas turbine does not pose any new lubricating problems, only extends two factors—temperature and speed. All other conditions should be easier than reciprocating internal combustion engines, because lubrication is not carried on in the presence of combustion and combustion products.

Designers of gas turbines are urged to consider designing for normal fuel oils, and to remember in packing their hell-fire pin wheel in small space, that all organic liquids break down at 650F.

Complete paper on which this article is based is available from the SAE Special Publications Department. Price 25¢ to members, 50¢ to nonmembers.

# Flight BEYOND the Earth

DIGEST OF PAPER* BY
Francis H. Clauser
Johns Hopkins University

(This paper will be published in full in SAE Quarterly Transactions)

REALISTIC appraisal shows that space travel is not just around the corner. It is most certainly going to have to await the development of high-velocity rockets with weights too low for easy attainment.

Existing powerplants might do the job, were we willing to pay the heavy price in overall weight that would be necessary. However, when we begin to compute the weights required if human beings are to be taken along as passengers with adequate provision for their health and safety, the astronomical numbers that result surely rule out such projects.

Space travel will come, but by gradual process of developing better sounding rockets, longer range rocket missiles, and eventually undertaking the construction of a full fledged space-ship, capable of leaving earth's gravitational dominance. The time scale? In decades rather than in years.

After World War I, space-travel societies sprang up all over the world in the age-old quest of means for voyaging to other planets. Skilled scientists and engineers saw in the rocket the only powerplant capable of producing enormous velocities out beyond the limits of the earth's atmosphere where air resistance and compression would not burn up a space vehicle.

After Hitler came to power, members of German society became interested in building a missile for long-range bombardment. Supported by the German army, the project resulted in the development of the V-2's which made London so uncomfortable in the last days of World War II.

From a purely engineering standpoint, the V-2's mark a very important stage in rocket development. The German version rose to altitudes of about 50 miles and traveled approximately 200 miles, and attained velocities of 4000 mph. V-2's fired at the White Sands Proving Grounds in New Mexico have gone to altitudes of over 100 miles.

The German V-2 demonstrated that liquid fuel rockets can be successfully used, and these give considerably better specific thrust than solid propellant rockets. It is necessary to expend a 12-ton vehicle in order to deliver one ton of payload at the target. The price becomes even steeper as we ask more of the rocket powerplant.

Successors to the V-2 will be in a position to accelerate to enormous velocities without worrying about the drag and heating caused by friction of the air.

If an object is projected out into space with a speed of seven miles per second, or 25,000 mph, it will travel out beyond the earth's gravitational field.

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*Paper Flight Beyond the Earth's Atmosphere* was presented at the SAE Detroit Section, Nov. 21, 1947.

The V-2 with its velocity of 4000 mph achieved about 16% of the required speed. Will it be possible to achieve the other 84%?

For the moment we shall neglect air resistance. As a rocket vehicle travels vertically upwards, the rocket thrust overcomes the force of gravity on the vehicle and at the same time provides an acceleration of the vehicle.

Weights to be considered are the payload, the total load of fuel and oxidizer used during the acceleration process, and the total remaining weight of structure, tanks, motors, controls, and so forth, that constitute the basic weight of the vehicle.

If the rocket thrust is nearly constant throughout the burning period, as is the case for the V-2, the vehicle will experience an initial accelerational load factor equal to the ratio of the thrust to the initial weight.

As the burning of the propellants takes place, the vehicle gets lighter in weight and its acceleration increases accordingly. The maximum acceleration will occur just before burnout of the rocket.

An exact analytical method for predicting the ratio of the structural weight to the instantaneous weight of the vehicle is virtually impossible to evolve because it depends to such a great extent upon the ingenuity and skill of the design engineer. However, a few simple facts are immediately apparent. The weight of a rocket powerplant and its associated parts is nearly proportional to the thrust produced.

The weight of propellant tanks will be proportional to the maximum load they carry. This maximum load will occur when the product of the load factor and the weight of propellants remaining in the tanks is greatest. It can be shown that for a constant thrust rocket, this product is greatest when the tanks are full. During rocket burning the propellant weight decreases faster than the acceleration increases.

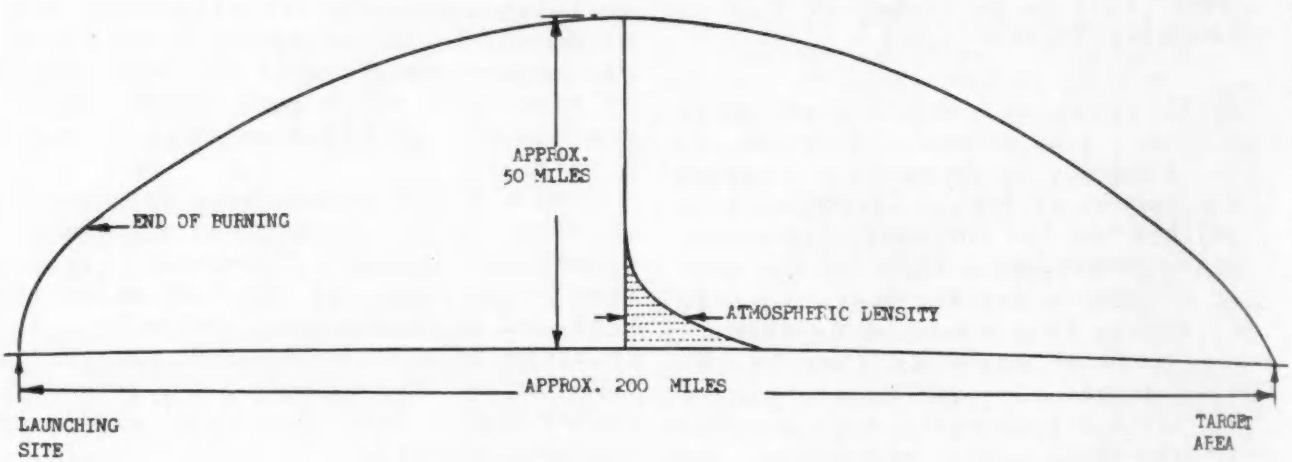
For a rocket vehicle, the rocket powerplant tanks and associated equipment constitute the major items of structural weight. Since these are proportional to the initial accelerational load factor, that is, the ratio of the thrust to the initial weight, we shall have a better indication of the effect of load factor on structural weight if we use this factor as our characteristic parameter instead of the maximum acceleration factor.

The operational V-2's had a structural weight ratio of about 0.24 for an initial acceleration of 2g. Later experimental models dropped down to 0.18.

One frequently sees rocket weights quoted as the ratio of the initial weight to final weight. Thus the weight ratio of the operational V-2 is 3.25 to 1.

Consequently, the weight ratio can be used directly in computing the performance

TYPICAL TRAJECTORY OF THE V-2



of a given rocket. However, in design work it is desirable to be able to determine the effect of changes in payload on performance. Such changes will, of course, alter the ratio of initial weight to final weight. Consequently, a single quoted value of this ratio is of little aid in design studies. It is for this reason we use the more fundamental weight ratios of structural weight to instantaneous weight and payload to the initial gross weight.

Preliminary experience has shown that as propellants are exchanged for payload, the change in tank weight just about offsets the change in weight of supporting structure for the payload. Therefore, the structural to instantaneous weight will stay nearly constant when payload-propellant changes are made.

It is interesting to note that the vehicle can attain velocities greater than the velocity with which the exhaust is being expelled. Under these circumstances, the exhaust will be traveling forward. The ratio of the instantaneous weight of the vehicle to its payload gives an indication of the size of the vehicle for a given payload.

The velocity ratio improves with decreasing ratio of total structural weight to instantaneous weight and increasing initial accelerational load factor. That is, it improves as less weight is used in structure and as less time is spent combatting the pull of gravity. However, it is impossible to take advantage of both these improvements simultaneously because increasing the latter adversely increases the former.

## PROPELLANT DETERMINES DESIGN

The velocity of the rocket exhaust cannot be arbitrarily selected by the designer. It is more strictly a characteristic of the propellants used, being determined to a large extent by the molecular weight, the temperature, and the specific heats of the combustion products. Other factors affect the exhaust velocity so little that it is possible to state the exhaust velocity of a given rocket with reasonable accuracy solely from a knowledge of the propellants used.

This table shows exhaust velocities of some of the best known rocket propellant combinations:

| PROPELLANT COMBINATION | EXHAUST VELOCITY | |
|---|---|---|
| | Fps | Mph |
| Nitric acid and aniline | 7300 | 4980 |
| Gasoline and liquid oxygen | 8070 | 5500 |
| Alcohol and liquid oxygen | 8100 | 5520 |
| Hydrogen and liquid oxygen | 8800 | 6000 |
| Hydrazine and liquid fluorine | 9740 | 6630 |
| Liquid hydrogen and liquid oxygen | 12,000 | 8180 |
| Liquid hydrogen and liquid ozone | 13,150 | 8970 |

It is seen that liquid hydrogen-liquid oxygen and liquid hydrogen-liquid ozone have quite high exhaust velocities. However, the fact that liquid hydrogen has a low density, a low boiling point, and a low heat of vaporization makes pumping, piping and storing extremely difficult. The high diffusivity of hydrogen makes sealing almost impossible.

This, combined with the fact that hydrogen and oxygen are violently explosive in mixtures anywhere from 2 to 98% makes them a dangerous combination. The liquid ozone combination is even worse because liquid ozone occasionally detonates spontaneously.

In order to overcome these difficulties, hydrogen-oxygen and hydrogen-ozone rockets will have to be unusually complex in their design with a resulting penalty in structural weight.

To avoid such drawbacks, alcohol and liquid oxygen were used in the V-2. Although these propellants have less exhaust velocity than liquid hydrogen-liquid oxygen, this is at least partially offset by the lower structural weight ratios possible.

Let us return to the problem of launch-

ing a vehicle into interplanetary space. It will be remembered that a velocity of 25,000 mph is required to escape from the gravitational pull of the earth. This is 4.5 times the exhaust velocity of an alcohol-oxygen rocket and 3.1 times the exhaust velocity of a hydrogen-oxygen rocket. Estimating that in the near future we might be able to build an alcohol-oxygen rocket with a structural weight to initial gross weight ratio of 0.15 for an initial accelerational load factor of 2 and a hydrogen-oxygen rocket with the former of 0.20 for the latter's 2, such rockets would fall considerably short of producing the desired velocities. In fact it would appear almost impossible to achieve the desired velocities with any combination of these factors that we could hope to achieve for many years to come.

This is a discouraging outlook. But the encouraging fact is that rockets are able to produce velocities which are a large fraction of the desired velocity. It is logical to ask if there is some way of using rockets to obtain the remaining fractions of the required velocity.

## MULTISTAGE ADVANTAGES

Earlier workers in the field saw that this was possible through the use of multistage rockets. To illustrate this concept let us consider a two-stage rocket.

We imagine our previously considered rocket being carried along as the "payload" of a much larger rocket. The larger rocket is fired first and when it has used up its propellants, it is discarded and the smaller rocket accelerates under its own power to even greater speeds.

Calculations show that a rocket with a large number of stages is not always superior to a rocket with a lesser number of stages. If high performance is not demanded of a rocket, that is, if we do not ask for velocities of the vehicle that are comparable to or larger than the rocket exhaust velocity, then the single-stage rocket, with its lack of multiple tanks, motors, and so forth, can be built with smaller overall gross weight to transport a given payload.

However, when the required performance becomes sufficiently high that the single-stage rocket required to do the job would necessarily be large compared to the payload, then it is better to use a two-stage rocket, with each stage sharing equally in producing the specified final velocity.

If even greater performances are desired, then it is preferable to use successively greater number of stages; there is no upper limit to the velocity that can be attained.

We see from figures for the multistage rockets that an envelope curve exists for each multistage family. This envelope represents the maximum performance that this family is capable of attaining.

Would it be feasible to use multistage rockets to launch a vehicle into space at the escape velocity of 25,000 mph? For alcohol-oxygen rockets the exhaust velocity is about 5520 mph, and the ratio of vehicle velocity to exhaust velocity that is required for escape is 4.5.

If we could build multistage alcohol-oxygen rockets where each stage would have a structural weight to initial gross weight ratio of 0.15 and each stage would start with an initial acceleration of 2g, then a velocity ratio of 4.5 could be attained with a 6-stage vehicle weighing 22,500 lb for each lb of payload.

For example, if we wished to have a 100-lb payload, then the entire multistage vehicle, assembled, ready to be fired, would weigh approximately 2,250,000 lb. This figure is forbiddingly large.

The only comforting fact is that more than 80% of this gross weight is in propellants which are easier to manufacture than motors, tanks, controls, and so forth. We see that one of the inherent shortcomings of a rocket vehicle is the large gross weight required to transport a relatively small payload, particularly when high performances are desired.

If we could build a hydrogen-oxygen multistage rocket with structural weight to initial gross weight ratio of 0.20 and with an initial accelerational load factor of 2, then the required velocity ratio of 3.1 could be obtained with a 5-stage vehicle weighing 2900 lb per lb of payload, or 290,000 lb for a 100-lb payload. This is a much more reasonable

CONTINUED ON PAGE 37

# "MAINSPRING"

EXCERPTS FROM TALK* BY **Henry G. Weaver** Director, Customer Research
General Motors Corp.

THE world has never lacked for inventions, but an invention (like a natural resource) is of little value in raising standards of living *unless* and *until* something is done about it.

America's first century of industrial progress was largely a matter of taking ideas of European origin, dusting them off, and putting them to work.

Our progress in mass production and mass distribution depends, not on a handful of geniuses, but on 140,000,000 free individuals - each with the everabiding ambition to try something new and something different.

One of the big differences between Americans and other people of the world is that we have never worried much about the hair-splitting boundary lines between the so-called necessary inventions and the non-essential gadgets.

The American techniques of mass production and mass distribution have continually and repeatedly shifted the benchmarks and pushed aside the artificial boundary lines and the luxuries of yesterday have become the necessities of today.

The motor car itself is a good example - and no one can deny that in the beginning it was little more than an expensive tinker toy.

Mass production of highly complex products could never have gotten started, except under conditions where men are free to live their own lives - free to plan their own affairs; free to try out new things; free to spend their own money - spend it any way they please and spend it foolishly if you please - on the yo yo tops, the bubble gum, and the so-called non-essential gadgets - in the never ending search to explore all the byways that may lead to progress.

That's the outstanding difference between free people and people whose needs, tastes and desires are regimented in line with collectivist theories.

It is quite true that freedom of choice results in a lot of waste. That's one of the favorite themes of the socialist and communist kibitzers. But such waste is the *price of progress*. The old must give way to the new and you don't have to hit

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*Talk based on his recent book "Mainspring - the story of human progress and how NOT to prevent it," presented March 31, 1948, at the dinner of the SAE National Transportation Meeting, Philadelphia. (Talbot Books, Detroit 2, Mich.)

the jackpot more than once in about a thousand times to more than balance the score.

The big contrast between America and other countries is, that while they are less wasteful of material things they are profligate in wasting the tremendous potentiality of individual initiative *which is the mainspring of all human progress.*

## 6000-YEAR ERROR

Down through the ages, for the 6000 years since the very beginning of recorded history, the standard pattern for improving the lot of mankind has been to suppress personal initiative and make the individual increasingly subservient to strong centralized authority. And for 6000 years people have gone hungry and still do over most of the world - in times of *peace* as well as in times of *war*.

For 6000 years the normal condition has been stagnation, poverty, distress and human degradation. Then in one small spot on this planet and in the brief space of 160 years, there has been a demonstration of progress beyond the utmost imaginings of all preceding generations.

Free minds are inventive minds and to me it is highly significant that so many of our revolutionary leaders were men of the inventive type:

Benjamin Franklin not only laid the foundation for the electrical industry but he invented the first pair of bifocal spectacles, the rocking chair, and a new type of stove which was the forerunner of the modern baseburner.

Also, and perhaps of even greater importance, it was the sly, tolerant, benign Franklin who invented the American sense of humor - based on the idea *"Don't take yourself (or anyone else) too seriously"!*

Thomas Paine had an inventive mind. With geometry as a hobby, Paine designed the first single span iron bridge with criss-cross girders.

Then there was Thomas Jefferson whose home at Monticello affords abundant evidence of his mechanical ingenuity. It was Jefferson who designed one of the first if not *the* first scientifically curved mold boards for a plow and it was Jefferson who supported the efforts of Eli Whitney.

Also it was Jefferson who organized the U.S. Patent Department which as Abe Lincoln later observed had "added the fuel of incentive to the fire of genius."

Since that time the United States has led the world in the number of patents issued: twice as many as Great Britain or France; four times as many as Germany.

But the greatest of all our inventions is not even recorded in the patent office records - in fact it's not usually thought of as an invention.

No, it's not mass production. It's far more important than mass production. It's the thing that made mass production possible.

This greatest of all inventions, and distinctly American, was the invention of an entirely new form of political structure, which represented a complete reversal of all the old world precedents and which was based on a principle that is just as fundamental - just as positive, just as open and shut, just as inexorable - as any basic law of physics.

*It is the principle that each individual is in control of his own life energy and that human initiative and creative ability spring from within and simply cannot be forced from without.*

Thus, for the first time in history, the Christian principles of self-faith, self-reliance, self-improvement, and individual responsibility were adopted as the foundation for a political structure. If you have any doubts on that point, try to rewrite the Declaration of Independence without reference to the Christian axioms. It can't be done.

So that, in the last analysis, is the reason why America is the Land of Opportunity and the Land of Progress.

That's why we've gone further than any other people in spreading the benefits of inventive genius.

That's why the people of the United States, who represent only 6% of the world's population, own:

80% of the world's automobiles,
54% of the telephones,
48% of the radio sets, and
46% of the electric power capacity.

And the United States with less than 6% of the world's population has 92% of all the modern bath tubs - that is, bath tubs with *running* water.

Before the war New Yorkers consumed 140 gallons of water per day, per person. Parisians used 47. Londoners only 43. (No figures on Moscow.) And before the war Americans consumed -

75% of the world's silk,
60% of the world's rubber,
50% of the world's coffee, and
40% of the world's salt.

Offhand the last item sounds a bit trivial. I was tempted to omit it but some of my economist friends tell me that the use of ordinary salt is one of the best indices of a nation's production and general standard living.

*Taking that statement at its face value leads to the startling conclusion that the people of the United States are exactly nine times better off than the average people in the rest of the world!*

It is interesting to note that this ratio was recently confirmed by no less a person than Gromyko and his fellow comrades at the United Nations when they contended that the United States, with 6% of the world's population, should pay 50% of the expense for running the United Nation's set-up.

As you may remember, Senator Vandenburg called their hand. He thanked them for the compliment and suggested that if we, by their own admission, were so much better off than other nations, then the first order of business should be the adoption by all the member-nations of the system which has put the United States in such an enviable position.

That, of course, was vetoed!

And Mr. Winston Churchill was talking much to the same point when he recently told the British Labor Party that they had broken the *mainspring of individual initiative* and that disaster could only be avoided by replacing and preserving the mainspring.

## SAE NATIONAL MEETINGS

| MEETING | DATE | HOTEL |
|---|---|---|
| WEST COAST | Aug. 18-20 | St. Francis, San Francisco |
| TRACTOR and DIESEL ENGINE | Sept. 7-9 | Schroeder, Milwaukee |
| AERONAUTIC and AIRCRAFT Engineering Display | Oct. 6-9 | Biltmore, Los Angeles |
| PRODUCTION MEETING and CLINIC | Oct. 21-22 | Statler, Cleveland |
| FUELS and LUBRICANTS | Nov. 4-5 | Mayo, Tulsa |
| | • 1949 | |
| ANNUAL MEETING and Engineering Display | Jan. 10-14 | Book-Cadillac, Detroit |
| PASSENGER CAR, BODY, and PRODUCTION | March 8-10 | Book-Cadillac, Detroit |
| TRANSPORTATION | March 28-30 | Statler, Cleveland |
| AERONAUTIC and AIR TRANSPORT | April 11-13 | New Yorker, New York |

# STRUCTURAL T

A full understanding of the importance of structural testing by management, production, and engineering is vital if maximum results are to be obtained from every dollar spent - and a full understanding involves the realization that (1) the desired results cannot be obtained by any process other than submitting the structure to actual test, and (2) predetermination of the exact time and cost involved is usually difficult, if not impossible.

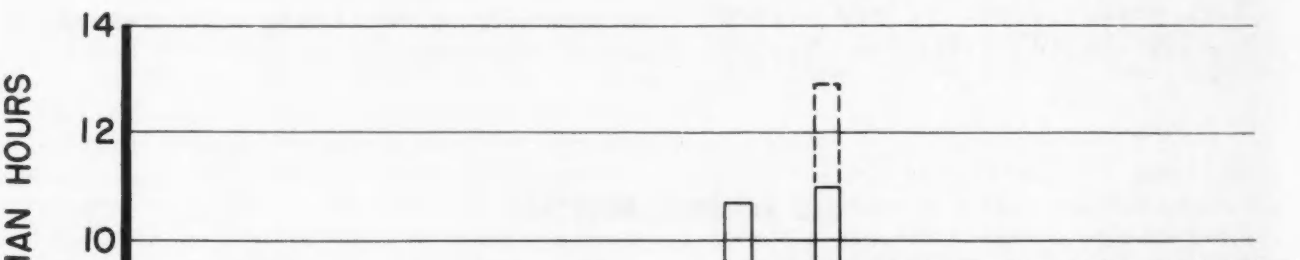
Structural testing and failures can no longer properly be considered problems for the structural department alone. Management, manufacturing, and other sections of engineering are regularly involved, as an analysis of the results desired and procedures used clearly indicates.

RESULTS DESIRED

If structural testing is to justify itself, it should attain the following objectives:

1. It should represent the final guarantee that proper allowance has been made for stress analysis assumptions, structural compromises, changes, and substitutions.

2. It should help the manufacturer reach the goal of having the plane suc-




●Fig. 1 - Chart showing how structural testing time has increased in last 10 years

# TESTING PAYS OFF

BASED ON PAPER* BY **S. A. Gordon and G. E. Holback**

Chief Structural Test Engineer — Assistant Chief Structural Test Engineer

Glenn L. Martin Co.

cessfully complete its qualification tests ahead of competition.

3. It should help create confidence in the customer.

Service failures are probably more serious in aircraft than in any other field of transportation. They can result in a loss of human life, manufacturing delays, and expensive service repairs. It is also difficult to find the basic cause of a service failure, especially in a serious accident where the evidence is destroyed or partially obscured.

Unlimited testing would, of course, not eliminate service failures entirely, because such a goal would require absolute perfection in the choice of the critical test conditions; but this limitation only emphasizes the importance of the constant application of good engineering judgment in the choice of test conditions.

In actual practice, the testing program is adjusted to suit the conditions peculiar to each airplane, with the general policies of the customer or licensing agency determining the amount of testing the manufacturer must do.

The overall policies of the airplane manufacturers' two main customers, the Army and Navy, and the Government licensing agency, the Civil Aeronautics Administration, can be summarized as follows:

The Bureau of Aeronautics generally requires that all structural tests be conducted by the contractor. Flight testing may proceed without static tests as long as certain flight restrictions specified in the contract are not exceeded. The manufacturer must, however, perform flight demonstration tests to the full limit load before the airplane is accepted. These latter flight tests cannot be performed until the flight restrictions have been lifted by successful completion of appropriate structural tests.

The Air Force generally requires that all structural tests be made by the procuring agency at Wright Field, although the contractor may conduct some tests for design information or for the release of the flight ship.

The CAA requires proof of compliance of the structure with certain strength and deformation requirements for all critical loading conditions. Proof of compliance by means of structural analysis will be accepted only when the structure conforms with types for which experience has shown such methods to be reliable. In other cases, substantiating tests are required. Certain portions of the structure, such as control surfaces, control system, and landing gear, must be tested. Most structural tests for commercial airplanes involve only proof tests because of the general use of conventional structures.

The way in which these general policies fit into the test program for each model depends on the answers given to the following questions:

1. Are full-limit-load flight demonstrations for some or all conditions necessary to establish acceptability of the aerodynamic characteristics of the

*Paper "What Price Structural Testing?" was presented at the SAE Aeronautic and Air Transport Meeting, New York City, April 13, 1948.

airplane?

2. Is the airplane an experimental or a production model?

3. Is the structure conventional or unconventional?

4. When and where would it be least expensive for a structural failure to occur? (Flight restrictions are assumed to be enforced, so failure would not occur in flight.)

Since the interpretation of test policies should be carefully established in the contract or certification requirements, it is of paramount importance that those who set up the policies and priorities have the necessary data to compare these factors in terms of test costs.

The record of engineering test manhours expended on 12 models for the three agencies over the last 10 years (as shown in Fig. 1) should prove helpful in analyzing costs. The curves clearly bring out the trend of increased structural test activity as required by the design engineers and the procuring or licensing agencies. It is believed that test requirements will stabilize in the future. Certain inefficiencies will be noted, which are attributable to the war and inexperience with increased and more complex test requirements. It should also be realized that most of the tests of the JRM-1 model were covered by tests of its prototype, the Mars.

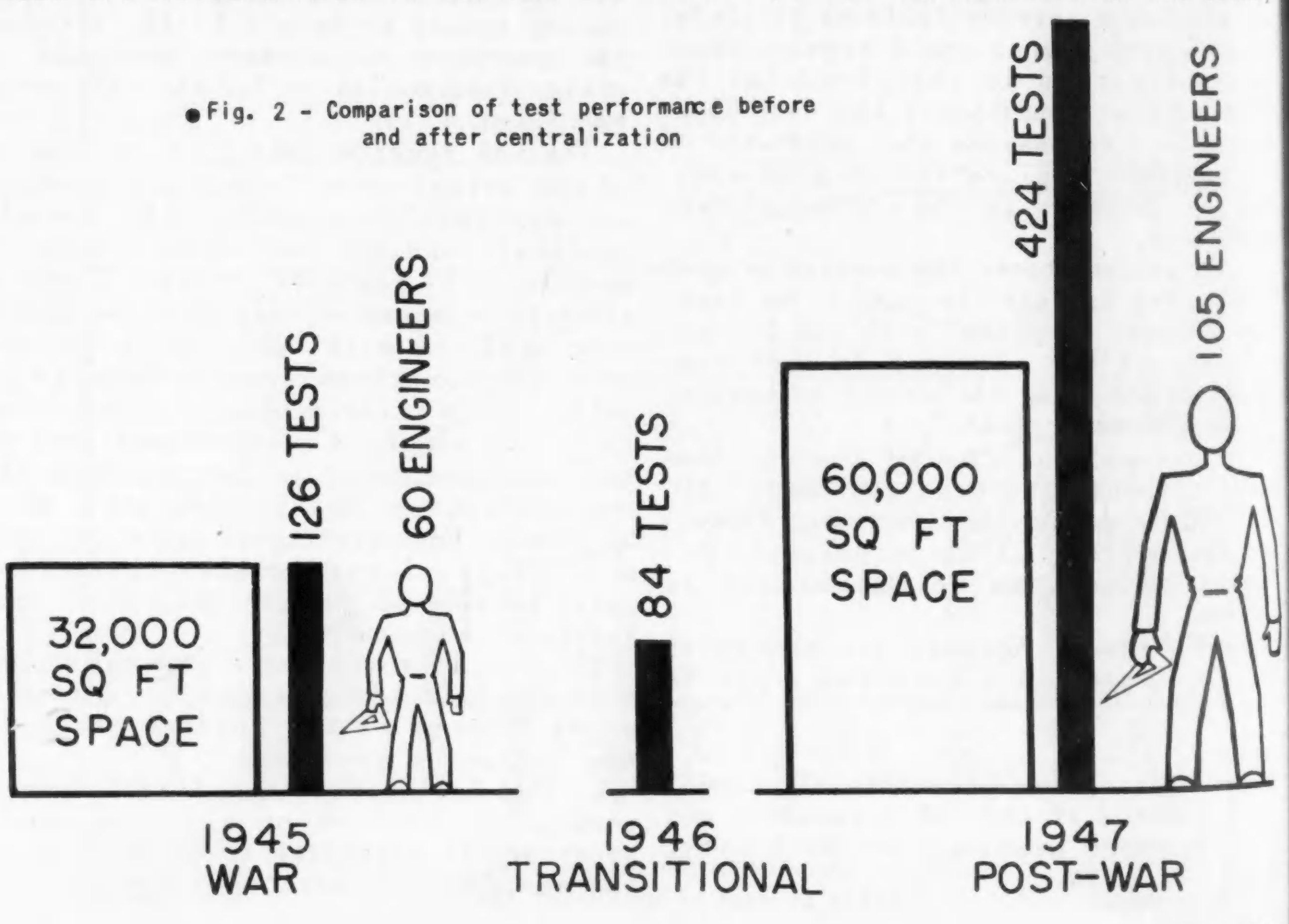
In determining the amount of testing to be done, it is important to avoid overemphasizing testing. Test engineers should be among the severest critics of new test work, because they should know best whether the test would be conclusive, and if something sufficiently similar had been tested before. They should always be on the alert to prove a test can be eliminated. Any unnecessary test work counts heavily against meeting the test schedule and the test budget.

## TEST PROCEDURES

A brief review of test procedures used will help to emphasize how each one affects the activities of all groups cooperating in the development work:

1. Limit load test: This test duplicates the maximum expected loads the airplane will encounter in service operation. It does not demonstrate the safety

● Fig. 2 - Comparison of test performance before and after centralization



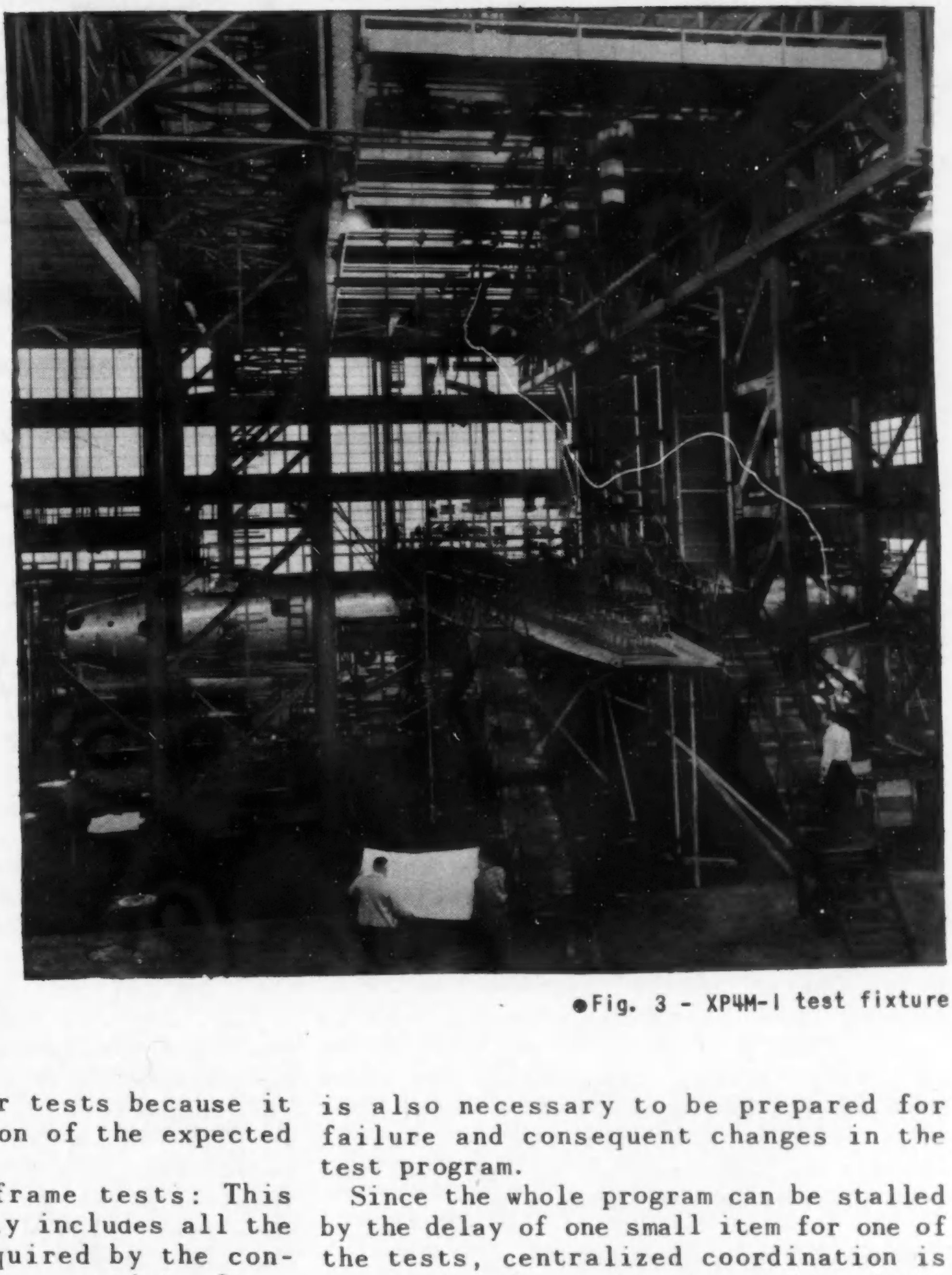
factor. In most cases, the specifications for these tests prescribe the extent of acceptable permanent set after the load has been applied. The test is performed to determine the rigidity and the operational characteristics of many of the mechanical components of an airplane while under load. Aircraft control systems, for example, require load test data on jamming, excessive deflection, and friction. Tests to determine load calibration for flight tests also fall into this category.

2. Ultimate load test: In this type of test the maximum or ultimate design load (which, of course, includes the safety factor) is applied to the structure.

3. Failing load test: This test determines the maximum strength of the structure and the primary mode of failure. This evidence may be translated into approval for increased gross weights or higher load factors and possible improvements in strength or weight of future versions.

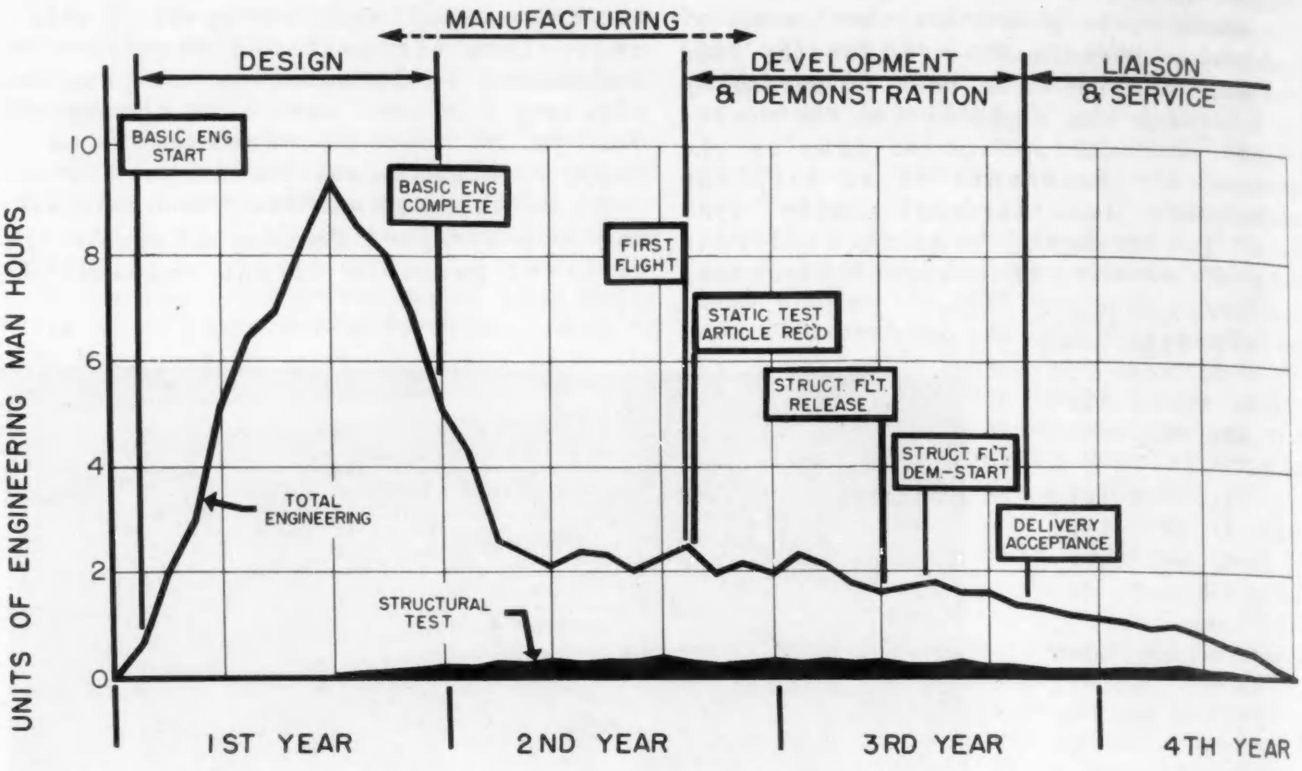
4. Repeated-load test: This test usually means the repetition of loading within the limit load range. It nicely complements the other tests because it provides an indication of the expected service life.

5. Complete airframe tests: This classification usually includes all the structural tests required by the contract. The program may consist of any combination of the tests already described. The main difference is that the tests are performed in sequence because there is usually only one specimen available. This circumstance requires coordination in formulating the program, planning the test sequence, timing the design of test fixtures so as to be ready to begin tests immediately on receipt of the test airplane, and maintaining uninterrupted testing to obtain the earliest possible flight release. It is also necessary to be prepared for failure and consequent changes in the test program.



●Fig. 3 - XP4M-1 test fixture

Since the whole program can be stalled by the delay of one small item for one of the tests, centralized coordination is required with complete knowledge of the test details, plus the cooperation of all associated groups.




● Fig. 4 - Average development cycle of typical airplane

6. Element tests: It is also necessary to test items of new design or unusual complexities, such as splices, wing cover panels, and special fittings. These tests must be completed before the design is too far along to permit a change. The tests require coordination between engineering, manufacturing, and tool departments to iron out the difficulties often involved in producing - for the first time - specimens incorporating unfamiliar design or new materials.

7. Research tests: These tests help to build the structural engineering background that keeps an organization in front. They include tests of such items as rivets, screws, compression and shear panels, for design allowable data. They also provide data for the structural evaluation and control of new fabrication procedures and materials.

## TIME AND COST FACTORS

It is not possible to set up ahead of time a schedule that will give the time of completion and the cost of each individual test in the program. Measures, however, that can be used to reduce them to a minimum include:

1. Provision of sufficient space for testing.
2. Clear-cut definition of responsibility.
3. Early and realistic planning.
4. Alternate test proposals drawn up.
5. Development of flexible test schedule.

Fig. 2 shows the savings that can be realized when good test facilities are made available in a centralized location. The comparison of the test performance in 1945, which was a busy year, with the performance during 1947 at a centralized location shows that test performance was more than tripled with less than double the floor space.

Flexibility is gained by being able to design fixtures high and clear of the specimen, as shown in Fig. 3. Then one

fixture can be used for all main test conditions, including drop tests.

The definition of responsibility in the test department organization should start with the contract or specification requirements, continue through test design and fabrication, test performance, analysis and preparation of reports, and end with final approval.

At the very start, the test engineers must take the time to determine the test program necessary to develop the design and to meet the structural specifications. The known technical problems to be investigated must be established (incorporation of new structural features, use of new materials, and planned extensive weight savings) and the interpretation of the test policies, contract, and specifications of the procuring or licensing agency must be interwoven into the test picture.

The test time span and how it affects the overall program must be considered. The average engineering man-hours needed for testing are compared to the average total engineering time data for five different models in Fig. 4 to indicate the development cycles of an airplane. From this figure it is evident (1) that structural testing is active for about 80% of the total time span for the project, and (2) that structural flight release must be planned early enough to permit the start of structural flight demonstration and the other structurally critical maneuvers necessary for aerodynamic evaluation. Actually, flight release is usually about 1½ months before the start of flight demonstrations.

In planning the schedule it is important to make sufficient allowance for unsatisfactory performance - since the elimination of such trouble is the whole purpose of the development and demonstration stage of a new plane.

As soon as the test program has jelled, the test engineer should develop several schematic overall test proposal drawings, based on the following considerations:

1. Optimum test sequence for early flight release and minimum repair in the event of failure.
2. Overall load requirements for design of test fixtures and loading apparatus to provide minimum test change-over time.
3. Space and handling facilities to speed setup and repair.
4. Tests that can be performed concurrently.

The test schedule must be sufficiently flexible so that failures occurring during the program do not prevent the completion of test fixtures and apparatus by the time the test specimens are delivered.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# Flight Beyond the Earth

CONTINUED FROM PAGE 28

figure and could not be ruled out on the basis of size alone.

If the multistage hydrogen-oxygen rocket could be built with the same values of 0.15 and 2.0 as were used in the alcohol-oxygen rocket examples, then the required velocity ratio of 3.1 could be attained with a 4-stage vehicle weighing 1000 lb per lb of payload, or 100,000 lb for a 100-lb payload. This illustrates quite forcefully the advantages to be gained by increased rocket exhaust velocities.

It should be remembered that the above figures must be corrected for air resistance. Such a correction affects only the first stage rocket in each case because the subsequent stages operate at altitudes well above the atmosphere. The experience with the V-2, which is comparable to that required for the first stage, indicates that the correction for air resistance is only a few per cent of the velocity. However, a few per cent change in velocity corresponds to much larger changes in gross weight, according to our curves.

Complete paper on which this article was based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# Cites Power Wants of

BASED ON PAPER* BY

Trevor Davidson

Chief Engineer
Bucyrus-Erie Co.

CONSTRUCTION machines need dependable, rugged engines and transmissions, suited to operating demands of each kind of equipment. Adequate power is a must for all of them, regardless of engine weight, because stalling can be costly. Machines for digging and hauling also require a wide high-to-low gear range in a small transmission package, with automatic shifting a real need.

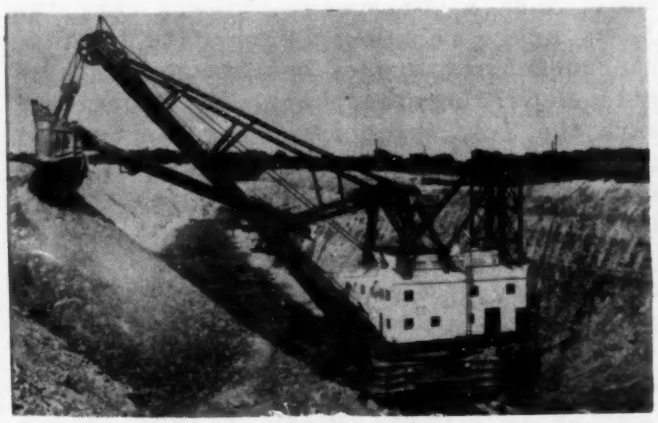
Operational characteristics of the two classes of excavating machines - those primarily for digging and those essentially for transportation - place quite different demands on their respective engines.

The first class, such as shovels and related equipment, involves three and sometimes four different motions engaged individually or simultaneously, derived from a single engine. To control these motions properly, the engine must run at substantially constant speed under governor control. Main power demand for tractor equipment and self-propelled machines in the second class is for traveling, with equipment control secondary. Engine speed is controlled to suit operating conditions.

Fig. 1 shows the general arrangement of machinery for an internal combustion engine-driven shovel. Engine weight is no

*Paper "Diesel Engines for Excavating Machines," was presented at SAE Milwaukee Section, Nov. 7, 1948.

## Some Earth-Moving



Shovel


Ripper

# Construction Machines

These mechanical beasts of burden establish tough transmission and engine requirements. This article examines implications of these needs for the several types of equipment in this field.

criterion since these machines are heavily counterweighted to balance the dipper and dirt. But confined space available in a machine built to meet highway or railroad shipping clearance favors a compact powerplant. This together with lower costs is forcing engine speeds up as quickly as engines can take it.

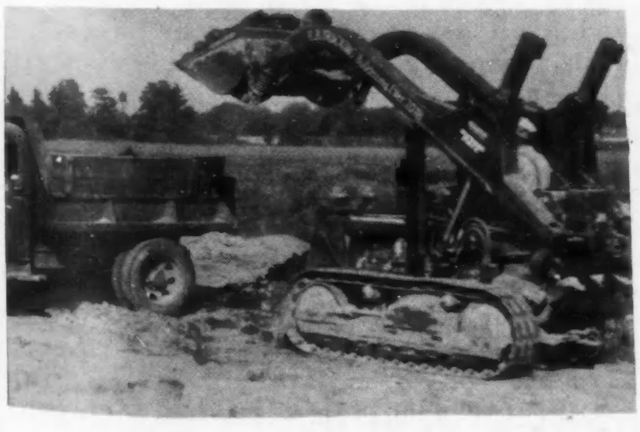
Demands on a shovel powerplant, like the one in Fig. 1, are unique. Its ability to tip the machine is a measure of the shovel's power. If the engine stalls before the machine tips, power is inadequate. Yet excess power will tip the machine too easily, so that extra ballast must then be added, increasing the loading in every part. Thus engine power must be well balanced to the machine.

Diesel engine power can be adjusted either through injection pump setting or engine speed. Average load on the engine is about 50% of full load, so fairly high pump settings are permissible. Tendency with tractor engines is to use standard pumps to prevent errors in servicing by the engine manufacturer; speed adjustment adapts power to the machine.

These machines perform a complete cycle - digging, swinging, discharging the load, and return - in 10 to 20 sec. At two or three points in the cycle engine demand will approach no load, and between these it approaches full load. In heavy digging, demand may exceed full load with the engine approaching stalling from once every two to three cycles to two or three times in one cycle.

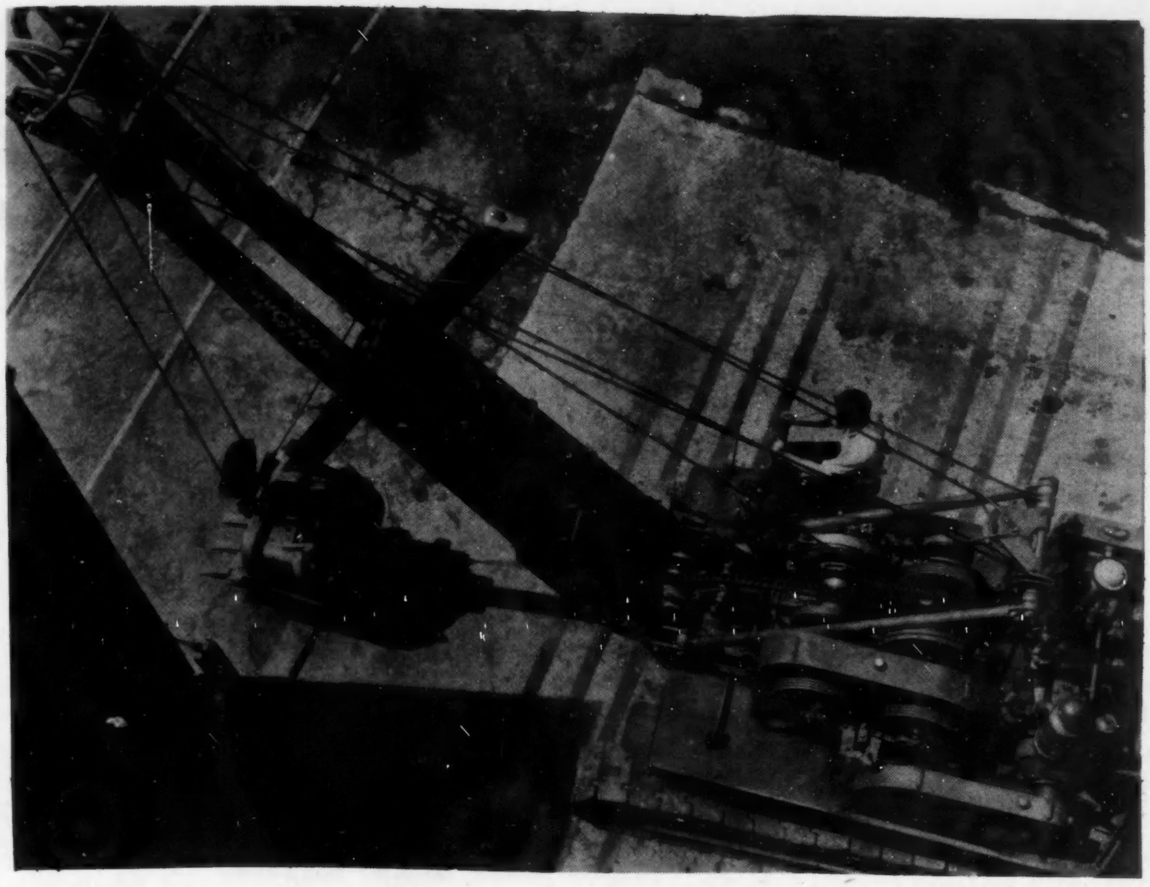
Crawler tractor engines, as in Fig. 2,

## Work Horses



Dozer Shovel

Scraper with Pusher



●Fig. 1 - The engine on this piece of shovel equipment drives through a take-off clutch at the back end; gearing to a clutch controls a drum on which cable is wound to raise and lower the dipper. Other clutches move the dipper in and out and rotate the machine

usually are designed for the tractors in which they're to be used, so adjusting an available engine to a certain machine isn't a problem here. But engine displacement and characteristics must suit tractor ability.

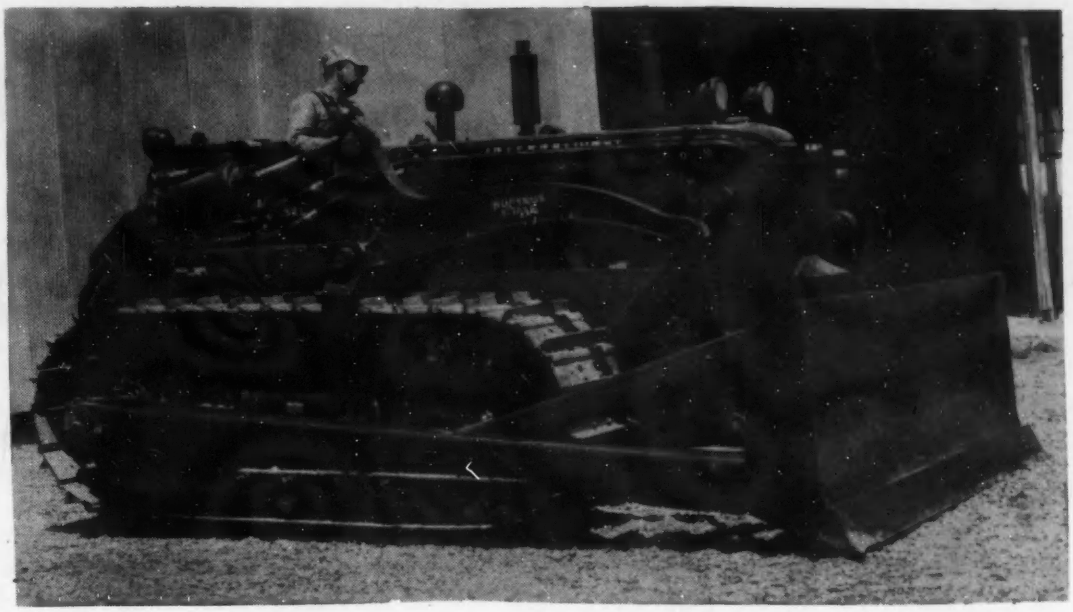
For example, the engine must slip the tracks on average ground with the weight of mounted equipment, otherwise the engine would stall easily and be underpowered. Excessive engine power penalizes the unit with high cost; the tracks will be slipped easily, digging into the ground and bogging down the tractor.

## COMPACTNESS DESIRABLE

Weight isn't too serious a problem since the tractor must be heavy enough to develop its tractive ability. However, reducing overall dimensions will improve operator's vision and engine accessibility, and reduce size and weight of mounted implements such as bulldozers.

These machines have multiple ratio transmissions; but engine characteristics don't particularly affect shifting since a crawler tractor generally comes to nearly a standstill during a shift. There are six or eight speeds available for a total range of 4 or 5 to 1 between low and high gears. Engines can be stalled with faster transmission speeds. But sudden stalling, more or less usual with shovels, is only occasional with tractors.

Engines for the second type of construction machinery, high-speed self-propelled units, operate under truck-service kind of conditions, except that the vehicle may be almost anchored to the ground by its cutting edge during digging. These units need enough power to slip the wheels on firm ground, with some excess for handling scraper controls to prevent engine stalling.



•Fig. 2 - Engines for crawler tractors such as this one generally are tailored to the machine

Since both engine speed and load vary widely to meet service conditions, maximum engine speeds and torque settings are permissible. A wide range between maximum torque speed and full load speed facilitates gear shifting. Low engine weight keeps gross vehicle weight down and betters flotation on soft ground. Shrinking overall dimensions improves visibility and angle of approach, leaves more room for driver in limited space around the large front wheels.

## TRANSMISSION CONSIDERATIONS

Transmissions pose a major problem in design of these construction machines. Some earthmovers operate on a 4 or 5-min round-trip cycle of digging, hauling, dumping, and return - with four or more shifts per cycle all day long. That's a lot of gear shifting. The machine digs in low gear at close to full engine power perhaps 20% of total operating time - a lot more low-gear operation than on the heaviest trucks.

This demands a wide range between low and high gear - 8 or 10 to 1; but conditions change too rapidly for effective use of numerous speeds with high selectivity. And room for a large transmission is at a premium.

Stalling is critical in all excavating machine engines. You could get maximum power with a fast-acting governor that would open wide at first sign of increasing demand; but this doesn't work out satisfactorily in practice, because range of governor regulation is tough to select.

The only way for the operator to judge power demand is by engine sound. He tries to run at slightly below full load to leave a margin of power for possible increase in demand which can occur suddenly. Establishing too narrow a range of governor regulation leaves too slight a difference in sound between partial and full load to be distinguishable. Result: the machine is apt to hunt between considerably less than full load and an overload approaching maximum torque.

Too wide a range of governor regulation produces an excessive loss in available effective power.

The ever-present stalling danger in excavating machinery operation justifies consideration of hydraulic clutches, eddy current clutches, hydraulic torque converters, and other slipping devices.

## COUPLING PROS AND CONS

Hydraulic clutches or fluid flywheels, sometimes used on shovels, reduce available horsepower and increase fuel consumption by the amount of slip. But this is not particularly serious. Where commercial

considerations or standardization with other equipment makes desirable an engine somewhat lacking in power for a particular machine, hydraulic couplings have improved performance. In these cases stalling possibility is greatly increased and in hard digging, the operator will tend to run the machine at even less demand to avoid time loss in restarting the engine.

## COUPLING NEEDS

Where there is enough power, hydraulic couplings offer little, if any, advantage. And there is some test indication that, because of its own inertia, the coupling may increase rather than decrease impact loading.

Hydraulic couplings were developed to operate on increasing speeds, where they perform effectively. Their torque rises about as the cube of speed so that they take hold smoothly with increasing engine speed. But if designed to stall at about 50% of full load, the coupling's torque capacity is about eight times stall torque; it might act almost as a solid drive for impacts at close to full speeds.

One manufacturer, according to reports, is testing an eddy current clutch and finds it better than a hydraulic coupling.

## CONVERTER DRAWBACKS

Torque converters can do a good job in certain types of service, in others it has definite limitations. For example, it has no place on shovels for these three reasons:

1. Output speed is variable, interfering with control.

2. Relatively constant engine speed precludes use of sound as a measure of loading.

3. Efficiency is low.

In tractor service torque converters offer advantages in view of (1) the amount of shifting done and (2) the fact that these machines come almost to a standstill during a shift. Although the theoretical disadvantages cited for torque converter use with shovels (together with greater engine wear because of higher average operating speeds) still hold in this case, advantages seem to outweigh the disadvantages. Maybe the theorizing is wrong, particularly since the largest tractor built was recently announced as featuring a torque converter.

These tractors have a three-speed transmission. Practice is to select the gear best suited for a particular job and to run continuously in that gear without shifting. The torque converter makes all required ratio changes.

Converters also seem logical for self-propelled scrapers because of the amount of shifting required. But since this machine requires an 8 or 10 to 1 transmission range between high and low gear, and maximum range for a converter is 5 to 1 (reduced to between 3 and 4 to 1 at reasonable efficiency), a three-speed gear box in conjunction with the converter is needed.

## OPERATOR'S PROBLEM

Throughout the shifting progression through all the transmission gears, the engine runs at about constant speed and load, except during actual shifting. Torque converter efficiency is maximum at about 2 to 1 speed ratio, drops off rapidly towards both stalling and 1 to 1 speed ratio. Thus, shifts must be made at the proper time. But the driver can't tell the proper time by engine sound because there is little change. He does not have time to watch a mechanically-operated indicator.

For this reason most believe that such combination transmission must be shifted automatically to be successful. No one yet has had the courage to attempt such a design for this much horsepower.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# PREIGNITION

# Traced to Three Sources

BASED ON PAPER* BY
A. Hundere and J. A. Bert
California Research Corp.

(This paper will be published in full in SAE Quarterly Transactions.)

BLAME for the destructive preignition which has been plaguing aircraft engines increasingly appears to belong on spark plugs, combustion chamber deposits, and exhaust valves. These three sources can furnish hot spots capable of causing surface ignition of the mixture before passage of the spark.

The spark plug offends when a piece of the insulator cracks off and is caught in the ground electrodes. The fragment, being thermally insulated from the spark plug body, grows hotter and hotter.

Deposits of lead sulfate and oxides of metals and silicon have melting points above the temperatures required for preignition. They can absorb enough heat in the solid state to touch off the mixture. It has been suggested also that since carbon deposits aided catalytically by lead compounds burn at temperatures as low as 680 F, carbon deposits can start preignition while they are burning away.

Since the exhaust valve metal may operate at 1400 F, it doesn't take much rise in temperature to put the valve in the preignition league, especially as a perpetuator of preignition already initiated.

When any one of these sources ignites the charge prematurely, high temperature gases are confined to the cylinder for a longer period of time than under normal ignition conditions. As temperatures climb, ignition tends to occur earlier and earlier in the cycle. Where detonation can be induced by ignition advance, it may accompany preignition.

Parts exposed to the high temperatures and pressures of preignition are the first to fail. Preignition can burn a hole through a piston in a matter of seconds, putting an aircraft engine out of operation. (Actually, preignition is possible in any engine compressing fuel-air mixtures, but it is more of a problem in aircraft engines, which are too highly stressed to withstand the increased temperatures and pressures that accompany preignition.)

## CRACKED PLUGS ONE SOURCE

The aluminum oxide insulators introduced in 1940 give today's spark plugs much higher preignition ratings than the older mica insulators - which dehydrated at operating temperatures above 1000 F, losing so much of their thermal conductivity that plugs reached preignition temperatures.

But the aluminum oxide insulators are subject to cracking, probably due to thermal shock. If the pieces fall clear

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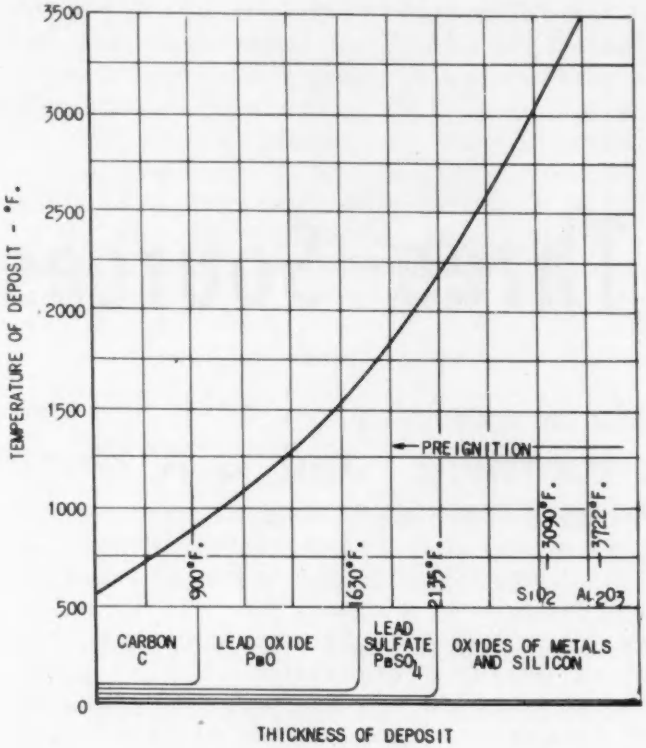
*Paper, "Preignition and Its Deleterious Effects in Aircraft Engines," was presented at SAE Annual Meeting, Detroit, Jan. 16, 1948.




●Fig. 1 - Combustion chamber deposits as function of temperature

of the electrodes, the preignition rating of the spark plug is only slightly influenced. If the pieces lodge in the electrodes, they continue to absorb heat without passing it along until temperatures are high enough to cause surface ignition.

The best way to avoid preignition due to cracked insulators is to use plugs with large clearance between the ground electrodes. Then ceramic fragments are less likely to be retained.

Preignition due to fragments in the electrodes is a serious service problem. One airline encountering piston burning was advised to examine the spark plugs from failed cylinders. In every case, they found a spark plug with one or more fragments retained by the electrodes. A laboratory test of a sample plug showed that it did give preignition. No preignition occurred when the fragments were removed.

Exhaust valve failures puzzled another operator. Here again, inspection of the spark plugs disclosed ceramic fragments in the electrodes.

In both cases, failures disappeared when plugs with large ground electrode clearance were substituted for plugs with fine clearances.

Any combustion chamber deposits which can achieve temperatures of around 2000 F are possible sources of preignition. Lead sulfate, formed from the lead and sulfur in the fuel, attains 2135 F before decomposing. Silicon dioxide, formed from dust inducted with air, melts at 3090 F. And although aluminum melts at about 1200 F, aluminum oxide melts at 3722 F.

An idea of how deposits can build up to preignition conditions can be gained from Fig. 1. The curve has been shaped arbitrarily to illustrate formation of deposits on a combustion chamber surface of 550 F. At this temperature, most of the deposits will be carbon. As deposit thickness increases, surface temperature of the deposit can increase. When the deposit builds up enough so that surface temperature reaches about 900 F, no more carbon will deposit. If temperature increases, lead oxide is next to be excluded at about 1630 F. Lead sulfate decomposes at 2135 F, leaving mostly oxides of metals and silicon as deposits.

As low-temperature-melting deposits are excluded, high-melting-temperature deposits are concentrated at the surface. And they are thermally insulated from the combustion chamber metal by underlying deposits. Under these conditions, high-melting deposits attain temperatures that cause preignition, even though the high-melting deposits constitute only a small percentage of the total deposits.

## LEAD MAY BE CATALYST

The carbon deposits, too, may cause preignition. According to a recently advanced theory, lead compounds deposited with carbon catalytically lower the ignition temperature of the carbon and enable it to continue to burn after the source of heat is removed. To back up the theory, data has been presented to show that lead compounds lower the ignition temperature of carbon from over 1200 F to 680 F - not a very high temperature for a combustion chamber. The data showed also that phosphorous compounds counteract the

catalytic effect of lead.

The undesirable tendency of lead to form deposits leading to preignition and the possible catalytic effects of lead compounds offset the desirable tendency of tetraethyl lead to inhibit preignition by metallic hot spots.

Combustion chamber deposits can initiate preignition even under mild cruise conditions. Fig. 2 shows an R-2600 piston that failed at 300 F cylinder temperature and 130 psi bmep. Many similar failures have occurred in engines operating on highly leaded fuels, especially under long sustained periods of constant cruise conditions with very low cylinder head temperatures. These are the conditions which foster growth of carbon deposits.

Often the failure occurs after cylinder head temperatures have risen abnormally and dropped back several times. The explanation for fluctuations may be that combustion chamber deposits begin preignition, then burn off or drop away before other sources of preignition heat reach the temperature to continue preignition.

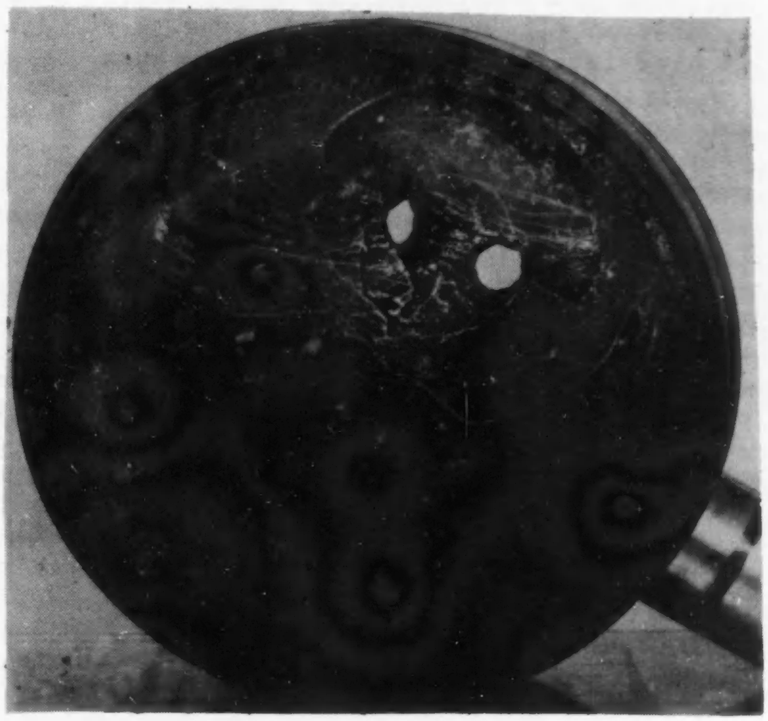
Exhaust valves are most likely to cause preignition when they are scaly. NACA preignition data obtained with a V-1710 cylinder show preignition obtained from the exhaust valve at a valve temperature of 1350 F when the surface was scaly. When clean and smooth, the same valve gave no preignition even at 1850 F.

## VALVES PERPETUATE PREIGNITION

When preignition is initiated by combustion chamber deposits, exhaust temperatures increase as ignition advances, and the exhaust valve runs hotter. If the exhaust valve reaches the preignition temperature before preignition from deposits stops, the valve can carry the preignition to engine destruction. This explains the absence of deposits in combustion chambers of cylinders known to have failed by deposit-initiated preignition. It also explains the extremely overheated appearance of the exhaust valves from preignition-failed cylinders.

No evidence has been found to support the theory that incandescent residual gases from the previous cycle cause preignition. Spark plugs, combustion chamber deposits, and exhaust valves are probably the only surfaces that attain temperatures sufficient for preignition in conventional aircraft engines.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.



• Fig. 2 - R-2600 piston burned by deposit-initiated preignition

# VERY-HIGH-SPEED FLIGHT

TWO types of cabin cooling systems - both employing air as the cooling medium, and suitable for use in conjunction with turbojet engines - have been developed to take care of the excessive heat that is generated at flight speeds over 600 mph. (See Fig. 1.)

The simple system consists basically of a heat exchanger, an expansion turbine, and a cooling air fan. Air is bled from the jet engine, cooled by passing it through the heat exchanger (which is itself cooled by ram air - air taken from the outside air stream), and is then further cooled by expansion through the expansion turbine. The power generated by this turbine is used to operate the air fan, which draws the air through the heat exchanger. Finally, the air is discharged from the turbine into the cabin at the proper air pressure.

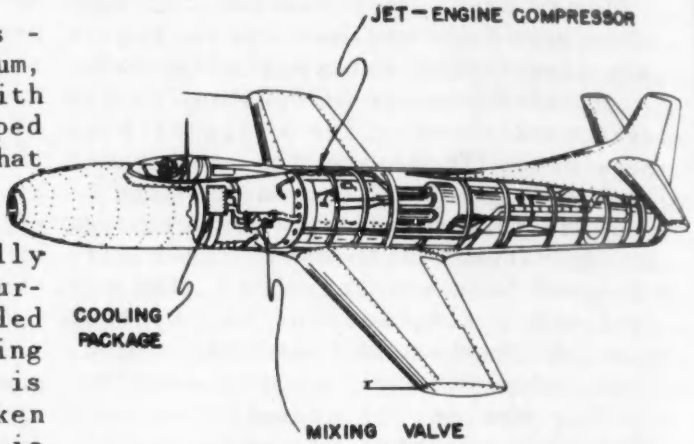
The bootstrap system utilizes two heat exchangers, combined with a centrifugal compressor and an expansion turbine. Air is bled from the engine, passed through the first heat exchanger, and compressed an appreciable amount in the centrifugal compressor. It is then cooled in the second heat exchanger, further cooled by expansion in the expansion turbine, and finally ducted to the cabin. The centrifugal compressor is driven by the power generated by the expansion turbine. Here again the heat exchangers are cooled by ram air.

## GENERAL CONSIDERATIONS

The choice of system for a particular airplane is based primarily on its cooling and pressurizing performance, although size, weight (including weight of ducting), drag, installation complications, and similar items must be considered.

The size of cooling equipment required for a given airplane depends on:

1. Airplane speed.
2. Airplane and cabin size.
3. Compressor bleed pressure and temperature available.
4. Cabin pressurization requirements.
5. Maximum duration of flight during critical operation or any specific cooling condition. Tolerance limits at different cabin temperatures and pressures vary with the duration of flight.




● Fig. 1 - Installation of cabin cooling equipment in typical jet airplane

Cooling is needed for very-high-speed operations because at these speeds the air stream has a very high kinetic energy content, which is converted to heat in the low-velocity boundary layer of air next to the airplane surface. Only a small per cent of this heat rise is dissipated to the air stream or lost by radiation or convection. The rest is absorbed by the airplane and its occupants. Fig. 2 shows how this ram temperature increases with speed. Actually, the temperature rise in the portion of the fuselage where the cabin is generally located is about 85% of the full temperature rise. The 85% curve is also shown in Fig. 2.

At high altitudes, cabin pressurization

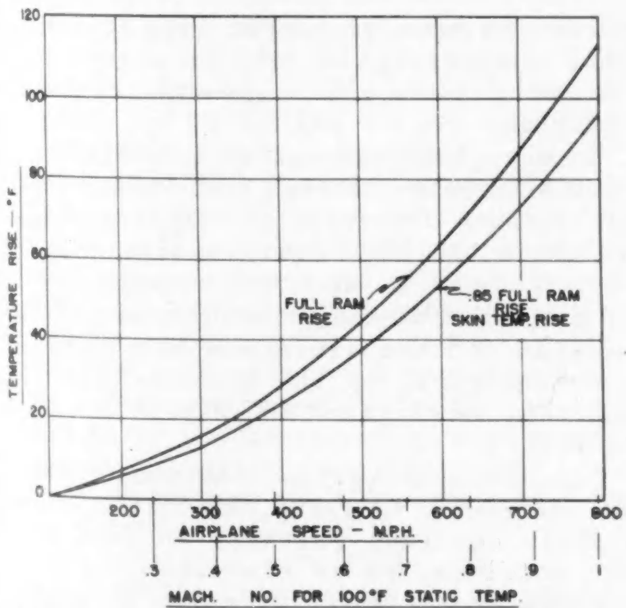
# Requires Cabin Cooling

BASED ON PAPER* BY
D. O. Moeller
Chief Engineer
&
O. A. Sanne
Project Engineer
Stratos Corp. Subsidiary of
Fairchild Engine & Airplane Corp.

is necessary to maintain pilot efficiency within minimum safety considerations. With the development of aircraft capable of flights above 50,000 ft, cabin pressurization will become more important.

A standard has been set up fixing the maximum differential between cabin pressure and outside air pressure as follows: Below 10,000 ft, no pressurization is used. Between 10,000 ft and 18,000 ft, the pressure is maintained at the 10,000-ft point. Above 18,000 ft, cabin pressure is maintained at least 2.75 psi above outside air pressure. These pressurization requirements dictate the minimum allowable cabin airflow, and thus may well be the critical design condition.

*Paper "Jet Aircraft Cabin Temperature Control" was presented at SAE Metropolitan Section Meeting, New York City, March 1, 1948.




●Fig. 2 - Effect of airplane speed on ram temperature rise

Pressurization introduces another problem - cabin leakage - which, at the pressurization standards just given, is 3-4 lb per min for jet fighters. Cabin leakage rate is also an important factor in determining the size of the cooling unit. Leakage rate is most critical at the altitude at which the ratio of compressor bleed pressure to cabin leakage rate is smallest. Once the cabin leakage at this critical point has been determined, the minimum rated airflow required at sea-level, rated conditions can be found in terms of pressure and temperature available from engine at this condition.

## HEATING APPLICATION

The air bled from the jet engine compressor is the source of cabin ventilation air, but it can also be used for heating purposes, if necessary, thereby eliminating the need for a cabin heater. This operation is controlled by a mixing valve, which automatically bypasses around the air-cycle cooling unit sufficient bleed air to keep the cabin temperature at the desired point. (See Fig. 1.)

In actual operation, the air-cycle unit operates at nearly full capacity even at very high altitudes; that is, only a small amount of the total air-bleed flow is bypassed around the cooling unit. At 40,000 ft, where the outside air temperature is -44 F, the cabin still demands 62% of the total flow to go through the cooling unit. The reason is that even when there is no cooling load, it is necessary to cool the hot bleed air from the jet engine to a reasonable mixture temperature, as dictated by the cabin heating requirements.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# PASSENGER

These definite safe limits of vertical vibration for human comfort are recommended:

A. *Low Frequency Range, $f$ = 1 to 6 cps*
Constant Maximum "jerk" Limit, $af^3 = 2$

B. *Middle Frequency Range, $f$ = 6 to 20 cps*
Constant Maximum Acceleration Limit: $af^2 = 1/3$

C. *High Frequency Range, $f$ = 20 to 60 cps*
Constant Maximum Velocity Limit: $af = 1/60$

where $f$ = frequency in cycles per second, and
$a$ = displacement (amplitude) in inches.

ON the basis of a study of all available experimental data on human tolerance to vertical simple harmonic vibrations, safe working limits for comfort are:

A. Maximum "jerk" value of 40 ft/sec$^3$ in the low frequency range of from 1 to 6 cycles per sec. ("jerk" is note of change of acceleration)

B. Maximum acceleration not more than 3.3% g in the 6 to 20 cps range, and

C. A maximum velocity limit of 0.105 in. sec in the high frequency range of from 20 to 60 cps.

The first of these represents a constant allowable maximum "jerk" limit, the second a constant maximum acceleration limit, and the last a constant maximum velocity limit.

Best current automobile design practice already conforms to the low frequency, or "jerk", value. This is lower than practically all the research observations reported as an "uncomfortable" sensation, but is slightly higher than the comfort limit in elevator practice.

Incentive to undertake this analysis of published work on effects of vibration on humans was provided by the SAE Riding Comfort Research Committee, and much of the data upon which it is based were originally made available through the work of that committee.

The derived limits of vibration based on research data represent an attempt to set a level at which no positive discomfort will be experienced by the most sensitive passenger.

Obviously, any study of vertical vibrations alone is insufficient, and interpretation of the resultant effects of complex vibrations, and the more complicated combinations of noise and vibrations, should be further investigated.

A simple correlation of the quantitative values obtained by the different investigators was thought to be inadequate. We have attempted also to establish the particular characteristics of the vibration which govern the human reaction.

In any vibratory motion, the displacement alternates between the extreme positions which determine the amplitude, and at which the body must instantaneously come to rest. Between the extreme points of displacement the velocity must reach a maximum and the vibrating body must be accelerated up to the maximum velocity and then decelerated to restore the body to rest.

Thus the acceleration changes throughout the cycle. Carrying this differential process one step further, we find that the acceleration is also changing at a varying rate - which we call "jerk" for want of an accepted succinct term.

The comfort reaction is determined

*Paper "Vehicle Vibration Limits to Fit the Passenger" was presented at SAE National Passenger Car & Production Meeting, Detroit, March 5, 1948.

# VIBRATION LIMITS

EXCERPTS FROM PAPER* BY
R. N. Janeway
Head, Dynamics Research Department,
CHRYSLER CORP.

basically by the maximum acceleration value of vibration in various frequency ranges.

The constant "jerk" frequency range of 1 to 6 cps has a direct bearing principally on the large body oscillations.

Compromises usually found necessary in calibrating the damping control of the suspension will ordinarily permit a maximum total body amplitude of 4 in., or a 2-in. displacement in its primary oscillation frequency on the suspension.

To keep this amplitude within the realm of comfort, the recommended limits indicate that the frequency should be held to 1 cps or 60 per min. This is in line with current good practice in vehicle suspension.

The lower end of the intermediate frequency range of 6 to 20 cps takes in the secondary vibrations originating in the unsprung or partially sprung parts of the vehicle's suspension system.

Resonant wheel bounce frequencies in automobiles usually occur at from 8 to 10 cps. To confine the transmitted intensities of these vibrations to the required low level, they must be suppressed at the source by dampening.

Vertical vibrations in the high frequency range of from 20 to 60 cps are likely to be disturbing if present at all because the comfort tolerance is low, and because vibrations in this range tend to be sustained.

High frequency vibrations are excited by (1) impacts originating at the wheels and transmitted through the suspension, and (2) alternating forces set up by unbalanced rotating masses in the automobile's engine.

The most effective protection against high frequency vibrations lies in eliminating the excitation at the source by proper cushioning of impact in the engine mounting and accurate balancing of high speed rotating parts.

One of the earlier investigators pointed out that the lower frequency vibrations, below 8 cps, seem to be centered in the abdominal organs; at higher frequencies vibrations appear to be transferred to the head.

This and further study of the fatigue induced by prolonged exposure to vibration is needed, and the interest of the anatomist and neurophysiologist is required if this is to be done adequately.

Any practical application of any criterion of human tolerance for vibration requires specialized instrumentation. The derived characteristics of human reaction have shown that the vibration spectrum can be divided into three ranges or bands of frequencies, in each of which a different measurable characteristic of vibration determines the sensation level.

A simple, direct reading instrument to measure comfort could be as easy to use as a noisemeter.

(Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers. Complete discussion presented following Janeway's paper is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

•Fig. 1 - The Lancaster's four wheeled bogie, experimental unit for tests

# EUROPEAN

OUTSTANDING developments in landing gear wheel disposition, the partial elimination of the landing gear itself, ultra-high pressure hydraulics, and flying control servos will undoubtedly be seen during the next few years.

The advent of large, high-speed aircraft poses two serious problems as yet unsolved. They are:

- Runway considerations and the use of multiple wheel undercarriages, and
- Stowage of multiple wheels, or wheels in thin swept back wings, or in the fuselage.

It is too early to establish well defined and scientifically based criteria for runway loading, and although the relationship between runway construction and wheel loading has not been determined, landing gear designers are certainly involved in multi wheel and load spreading layouts.

General performance of a four wheel nonretractable bogie, Fig. 1, was tested in 1944 by the Electro-Hydraulic Co., then Messier Aircraft Equipment Ltd., and flight tests proved it satisfactory. However, the pivot axis was too high for complete safety.

On one of its landings the Lancaster landed on the front wheels, tip toe fashion, because the resultant force on the front wheels passed under the pivot, forcing these wheels down, braking the articulation stops and jamming the rear wheels against the landing gear frame. The aircraft fell back on all four wheels when the speed dropped.

To prevent the difficulty described, the articulation axis should be as low as possible, and close to the wheel axle plane, or at least the correct side of a 0.8 W drag resultant from the ground at touch down.

We consider several four wheel bogie layouts, Fig. 2, interesting. They are variations of the experimental unit for the Lancaster. Directional stability of this type of bogie is considerable, and turning requires appreciable force to be exerted by the nosewheel. Following World War I the Bristol Braemar with tandem main wheels without brakes proved to be virtually unturnable because it had no steering nose wheel.

We know too little of the exact relationship between turning radius and torque set up in the landing gear, and our knowledge of the cornering power at appropriate yaw or slip angles with modern

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*Paper "European Landing Gear Developments" was presented at SAE National Aeronautic & Air Transport Meeting, New York City, April 15, 1948.

# LANDING GEARS

BASED ON PAPER * BY **H. G. Conway**

Technical Director, British Messier, Ltd.

high pressure tires is limited.

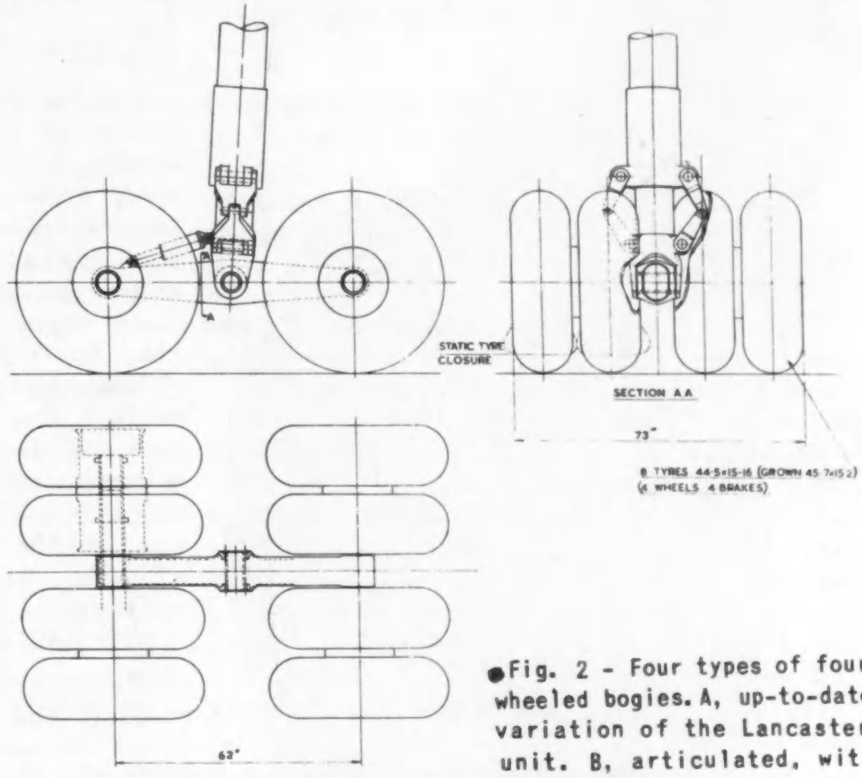
The eight wheeled gear, Fig. 3, appears to be a competitor of the track landing gear for use on soft ground with contact pressures as low as 20 psi. Obviously heavy, it is probably lighter than a track, and more simple.

Stowage problems are considerable. Multi wheel bogies can be retracted into a wing reasonably well, but an extra hydraulic cylinder or mechanical linkage will be required to rotate the bogie with respect to the shock absorber during retraction.

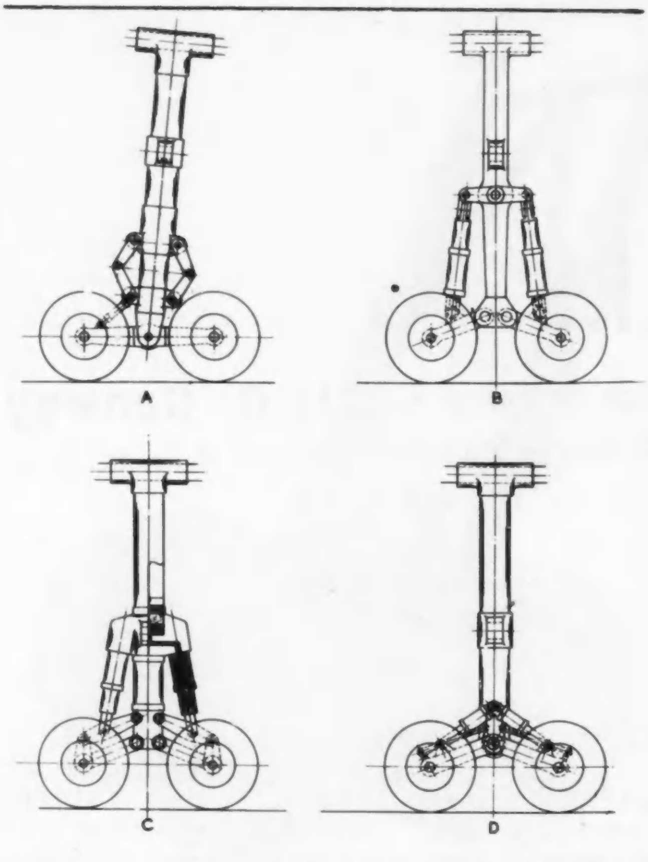
Because of the relatively thick all wing construction of the delta type aircraft, stowage of the landing gear might be easier than on an ordinary swept back design.

Many of us believe that the day will come when many aircraft will have no landing gear. The German Me. 163 and the Ardo 234 had skids, and may be a foretaste of the future. Some feel that in the near future we will see naval, mail, and other types either with skids or no landing gear at all

The Me. 163 was heavy, its shock absorption poor enough to have injured several pilots. Take off required a pair of wheels that were jettisoned when the




●Fig. 2 - Four types of four wheeled bogies. A, up-to-date variation of the Lancaster unit. B, articulated, with single shock absorber, used on Consolidated B-36. C, similar scheme, but with hydraulic instead of mechanical interconnection of absorbers, and D, a further variation to be used with Dowty liquid spring shock absorber. This is to be used on subsequent. Note that brake transfer can be eliminated by parallel linkages




• Fig. 3 - Considerably more simple than a track for low pressure duty is this eight wheel bogie, although it would be heavy

airplane was airborne, and a tractor with a lifting fixture in tow was used after the ship landed.

Certainly the possibility of recuperating some or all of the 5 to 7% gross weight represented by landing gear is a most attractive idea.

A skid landing gear was designed by the author for the Ministry of Supply. This used an arresting system proposed by a Government engineer.

Takeoff is by catapult, auxiliary trolley, or some other convenient method. Landings were made on a small prepared patch of tarmac, a bituminous road building material. This surface was lubricated to reduce the coefficient of friction to about 0.15 max, which reduced the side and drag loads.

The energy to be absorbed corresponds to a vertical velocity of 12 ft sec, the acceleration factor developed being 3 (limit) or 4 (ultimate), which is normal British practice. A naval arresting gear was used for retardation, and a skid "tire" was used to enable the skid to pass over the arrester wire to prevent damage.

Fig. 4 shows the layout of the skids as they might appear on a jet propelled fighter. Weight saving is appreciable.

Although our tire construction practices are similar to yours, we have lagged in high pressures in Europe. New RAF and civilian planes do not exceed 100 psi, 120 psi is being discussed, but your 150 to 200 psi range is not even contemplated.

Major O. J. Marstrand's twin contact tire, Fig. 5, is inflated at about 60 psi. Due to the separation of contact bands it prevents shimmy. It is at least 30% heavier than the normal tire, even when the contact bands are ribbed or studded.

Dunlop's Compacta is a tire in which the crown is flattened by circumferential cords of rayon or nylon. It has a large width diameter ratio and eight 48 in. tires of this type were used on the later versions of the Brabazon, inflated to 100 psi.

Disc brakes are the trend in England and France, as in the United States. Germany brought out this type in 1944, and any European aircraft with drums simply indicates some commercial or production consideration.

The Goodyear single disc brake aroused interest in Europe. A new Dunlop plate brake on the Airspeed Ambassador breaks away from the company's long use of expander tubes. The Messier Multispot brake has discs more protected than several other designs. The pads are disposed radially round the discs with gaps between them for ventilation.

Most modern British aircraft are designed for a retardation of about 10 ft per sec or 0.31 g. This corresponds to a drag load ratio on the main wheels of about 0.4. This seems about all the pilot can handle without risking locked rear wheels. Nosewheel braking was found wanting.

All RAF and most British civil aircraft have hand operated brake pressure control and rudder bar differential action. France is replacing this method with the American foot operation, but we have decided to continue with finger operation.

Although European and American shock

struts are similar except in detail, there are bigger differences in these among our equipment manufacturers than between yours. The Dowty liquid spring seems to have proven to be reliable, but not necessarily more so than an ordinary air-oil unit.

If oil can be sealed at 60,000 psi satisfactorily, surely we can do better at 4000.

France has developed retracting landing gear with hydraulically operated telescopic tubes for legs. Such shock absorbers appear to have been used occasionally in America.

Where articulated landing gears are used the mechanical shortening of folding, a suitable linkage or shock strut mounting can be used to double the fork up during retraction. This is done on several British aircraft.

In France this is done hydraulically. One system closes the shock absorber by an external cable, the retraction pressure having opened a hydraulic lock. This allows the fluid to bypass into a lateral accumulator, itself inflated at a low pressure sufficient to extend the leg. The two volumes of oil form a closed circuit, but the weight of the aircraft is taken on a hydraulic lock.

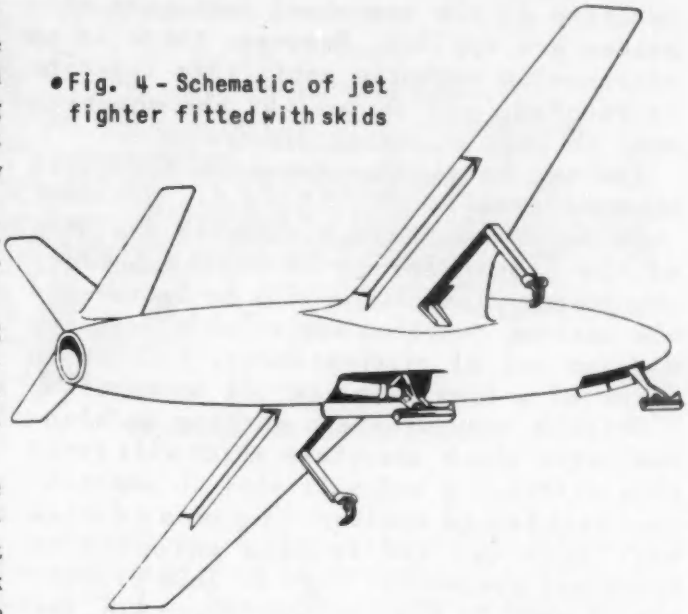
In another system the shock absorber is pumped shut by pressure, and the fluid from the shock absorber is expelled into an accumulator.

An external cable closes the unit in still another system, and the storage capacity being located conveniently between the sliding tube of the gear and the absorber.

Weakness in each of these systems is that leak-proofness of a valve is relied upon for a safe landing. A special type of dual seal valve has been developed, but no one in Europe recommends their use where avoidable.

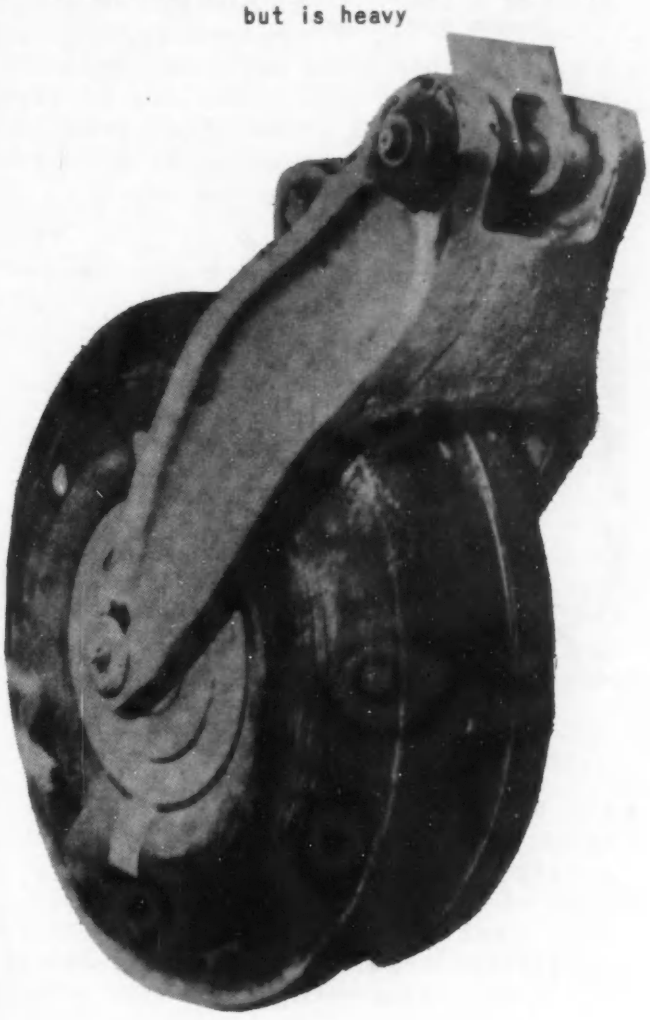
We have experienced some difficulty in providing adequate energy absorption capacity while braking when ordinary shock struts are applied to the nosewheel. When brakes are applied, due to the relatively high moment of inertia ($K^2/a\ b$ = 1.5 to 3) the velocity of pitch is much less. Therefore, the efficiency of energy dissipation is very low.

Conditions to be dealt with are shown diagrammatically in Fig. 6. The steady



•Fig. 4 - Schematic of jet fighter fitted with skids

•Fig. 5 - Marstrand tire showing separation of contact bands to prevent shimmy, but is heavy



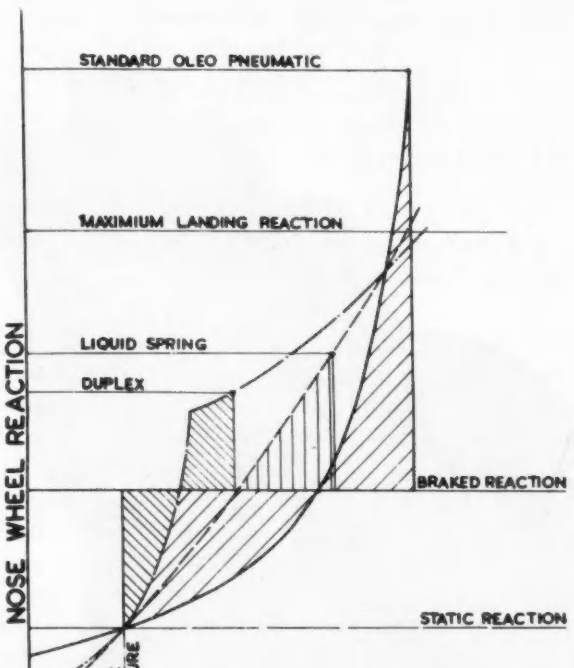
reaction on the nosewheel increases when brakes are applied. However, there is an increase in momentum until this reaction is reached, and thereafter the momentum must be lost or energy dissipated.

The two hatched surfaces on the curve must be equal.

Since the elasticity curve in the case of the liquid spring is nearly linear, the energy dissipation will be better and the maximum reaction appreciably less for a given set of circumstances. This is in favor of a liquid spring for nosewheels.

British companies are working on oleo-pneumatic shock absorbers which will avoid this difficulty and will show an improvement over liquid springs. One uses a duplex unit with two air volumes inflated to different pressures, Fig. 6. This principle is used by Electro-Hydraulics Co. for the handley Page Hermes 14 transport.

In France, where grass landing fields are still common, interest has been shown




• Fig. 6 - With ordinary shock absorbers, hydraulic damping effect is virtually nil and action is entirely on air curve, which at low speed is probably between isothermal and adiabatic (p.v. 1.2 = constant). Final reaction will be relatively high

in variable orifices which are enlarged for taxiing. In England we have not thought this necessary, and there is some doubt about the reliability of their operation.

France has always led in hydraulic pressures. In 1937 Olear installed equipment to operate at over 5000 psi. At least two British companies are ready to produce 4000 psi equipment.

You have Christiansen's O-Seal in America. France has used single rectangular seals since about 1935. In 1936 the Messier double ring seal, with a hard outer ring for wear and a softer inner ring for elasticity, was evolved. Dowty and Lockheed have used simple rectangular rings in England since 1938. Dowty's liquid spring seal functions adequately at 60,000 psi, and with no difficulties with seals at 4000 psi.

Dowty is faithful to its Live Line variable delivery pump at 2500 psi working pressure. Two constant delivery pumps for the 4000 psi system are available. Messier has a new swash plate unit with a valve arrangement giving uni-flow action.

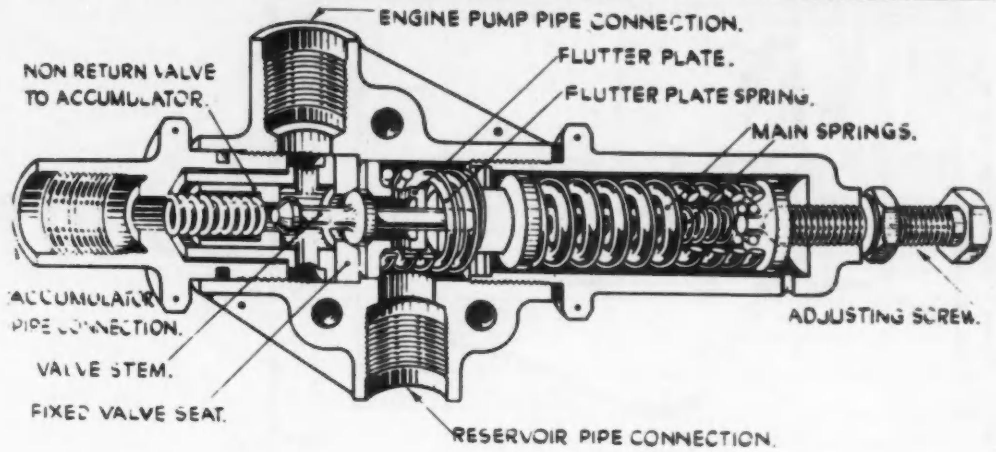
Most unusual unloading valve in conception as compared with American designs is a Lockheed's device, Fig. 7. Pump-to-flow is through a non-return valve formed by the piston seat. Pressure under the valve overcomes the three spring loading, opening the valve. The fluid opens the secondary plate loaded by only one spring. Thus the pressure drop from the pump to reservoir occurs in two stages. The difference in diameter of the valve and piston creates the desired pressure differential.

When braking loads on French and British planes became too much for the pilot, the trend followed the American pattern and adopted pneumatics. De Havilland, Dove, Percival Merganser, Miles Marathon, Short Sealand, and Boulton Paul Balliol have dispensed with hydraulics and use the brake pneumatic system to operate the complete system, including landing gear.

•A compressor can handle a greatly increased output volume because the weight of air entering is proportional to the boost pressure.

•Pressures of at least 1000 psi can be

•Fig. 7 - Cut-out valve by Lockheed




obtained with a two stage compressor.

•Compressor weighs no more than does the aspirated type.

•Delivery pressures and output are maintained at the highest altitudes now contemplated.

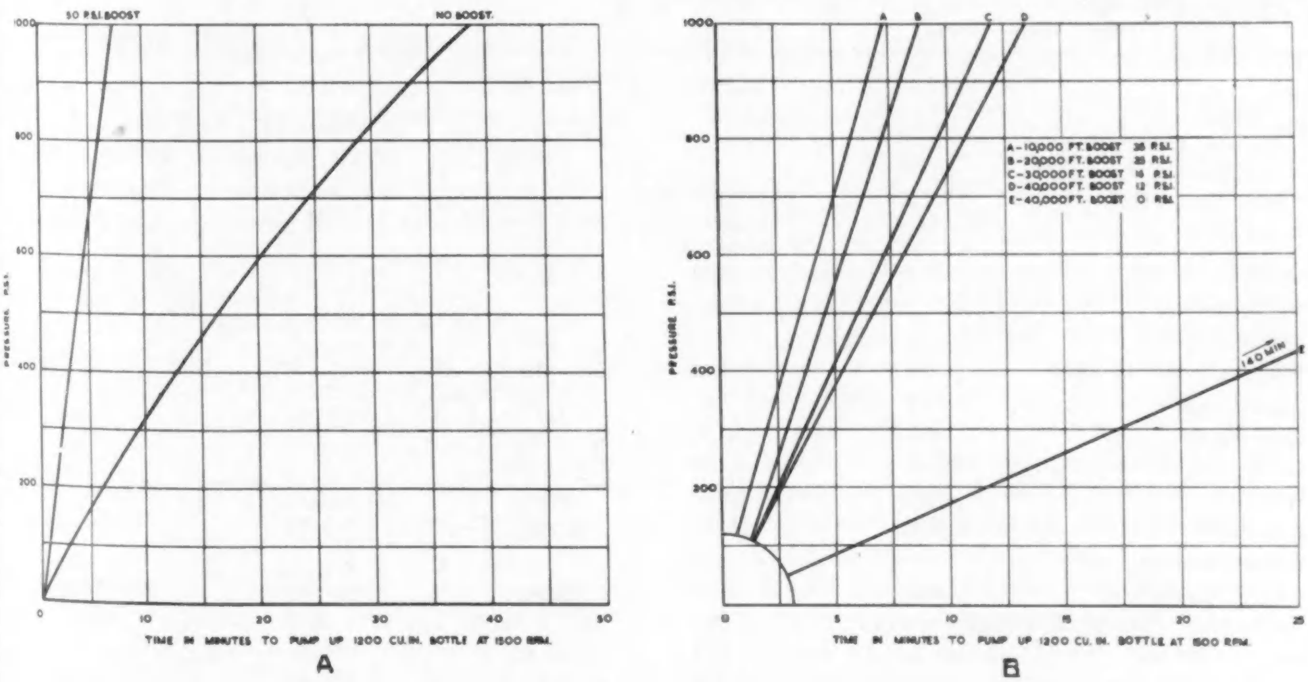
•Valve design is less critical than for a normal aspirated compressor.

•Small bottles can be used because they are recharged rapidly.

How supercharging strikingly improves performance of the Heywood high pressure compressor, as an example, is shown in Fig. 8 A, where the ground level output is increased 5.67 times, with no increase in compressor weight and only a small penalty due to coolers.

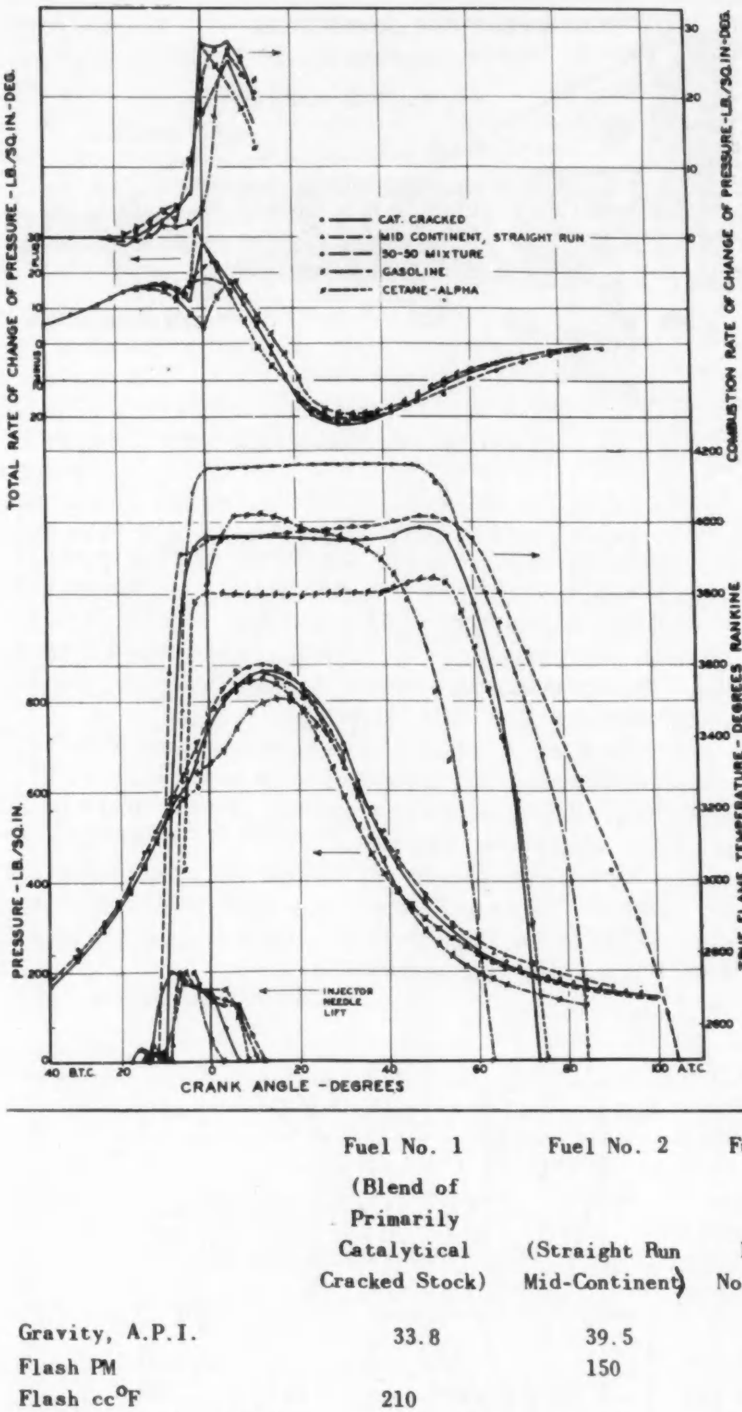
Output at high altitudes is so greatly improved that comparisons are difficult. Fig. 8 B indicates gains from a particular turbine engine.

Complete paper on which this article is based is available from SAE Special Publications Department. Price 25¢ to members, 50¢ to nonmembers.




•Fig. 8 - How supercharging to 50 psi improves performance of high pressure compressor is shown at the chart on right. Chart on left shows greatly improved output at high altitudes

# Diesel




●Fig. 1 - Combustion data for five different fuels with medium injection

*Paper "Diesel Combustion Temperatures- Influence of Fuels of Selected Combustion," presented at SAE Annual Meeting, Detroit, Jan. 15, 1948, will be printed in full in SAE Quarterly Transactions. Paper "Diesel Combustion Temperatures," was presented at SAE Milwaukee Section, Dec. 5, 1947.

TABLE 1 - DIESEL FUELS TESTED

| | Fuel No. 1 (Blend of Primarily Catalytical Cracked Stock) | Fuel No. 2 (Straight Run Mid-Continent) | Fuel No. 3 (50/50 Blend of No.1 & No.2) | Fuel No. 4 (Blend of Normal Heptane and Iso-Octane to give 40 Cetane) | Fuel No. 5 (Blend of Cetane and Alpha Methyl Naphthalene to give 40 Cetane) |
|---|---|---|---|---|---|
| Gravity, A.P.I. | 33.8 | 39.5 | 36.7 | 72.9 | 21.2 |
| Flash PM | | 150 | | | 225 |
| Flash cc°F | 210 | | 185 | | |
| Viscosity SUV at 100F | 41 | 34 | 36 | | 33.3 |
| Cloud Point | -10 | 0 | -10 | | 40 |
| Pour Point | -10 | -5 | -10 | | 40 |
| Color | 1½ to 2 | 1+ | 1¼ | | 1+ |
| Doctor | sweet | NG | sour | | OK |
| % Sulphur | 0.219 | 0.25 | 0.199 | 0.0097 | 0.87 |
| Carbon Residue (10% Residium) | none | 0.011 | none | | 0.058 |
| Corrosion, Cu Strip, 212F | no.1 strip | OK | no. 2 strip | OK | Ok |
| Gum, Mg/100 cc | 43.4 | 6.2 | 52.4 | 1.0 | 13.8 |
| Analine Point °F | 134.6 | 150.2 | 145 | 153.8 | 96.4 |
| Diesel Index | 45.5 | 59.3 | 52.23 | 112.1 | 20.4 |
| Cetane No. | 41 | 54.0 | 46 | 40.0 | 40.5 |

# Fuels Probed

BASED ON PAPERS* BY
**P. S. Myers**
&
**O. A. Uyehara**
Mechanical Engineering Department
University of Wisconsin

RELATION of diesel fuel's combustion performance to its physical properties slowly is emerging from tests under way at the University of Wisconsin since 1942. Small maximum temperature and pressure differences found in the five fuels tested (Table 1) point to need for extreme experimental accuracy.

As Fig. 1 shows, combustion temperature for the fuels actually are small, expressed as percentages of the absolute temperatures. The straight-run fuel gave highest temperature; cetane-alpha mixture, the lowest.

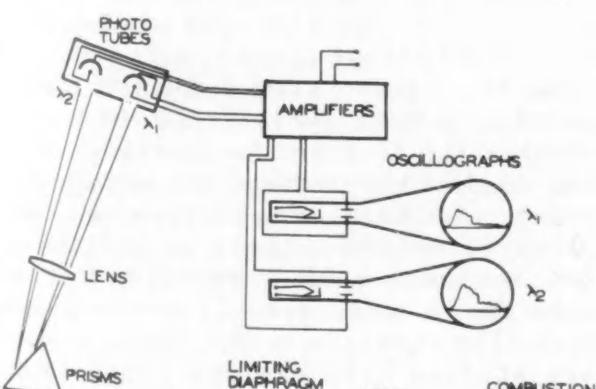
The cetane-alpha mixture also produced the highest and earliest total rate of pressure change.

Interestingly enough, despite variation in crank position for peak rate of pressure change due to combustion, peak values didn't differ much between fuels. Curves for this rate of change also indicate release of some heat by all fuels before main combustion.

Another item revealed by the test data is that all fuels, except cetane-alpha mixtures, give lower combustion temperatures at earlier points of injection. Whether this reversal of trend of the cetane-alpha mixture stems from one of

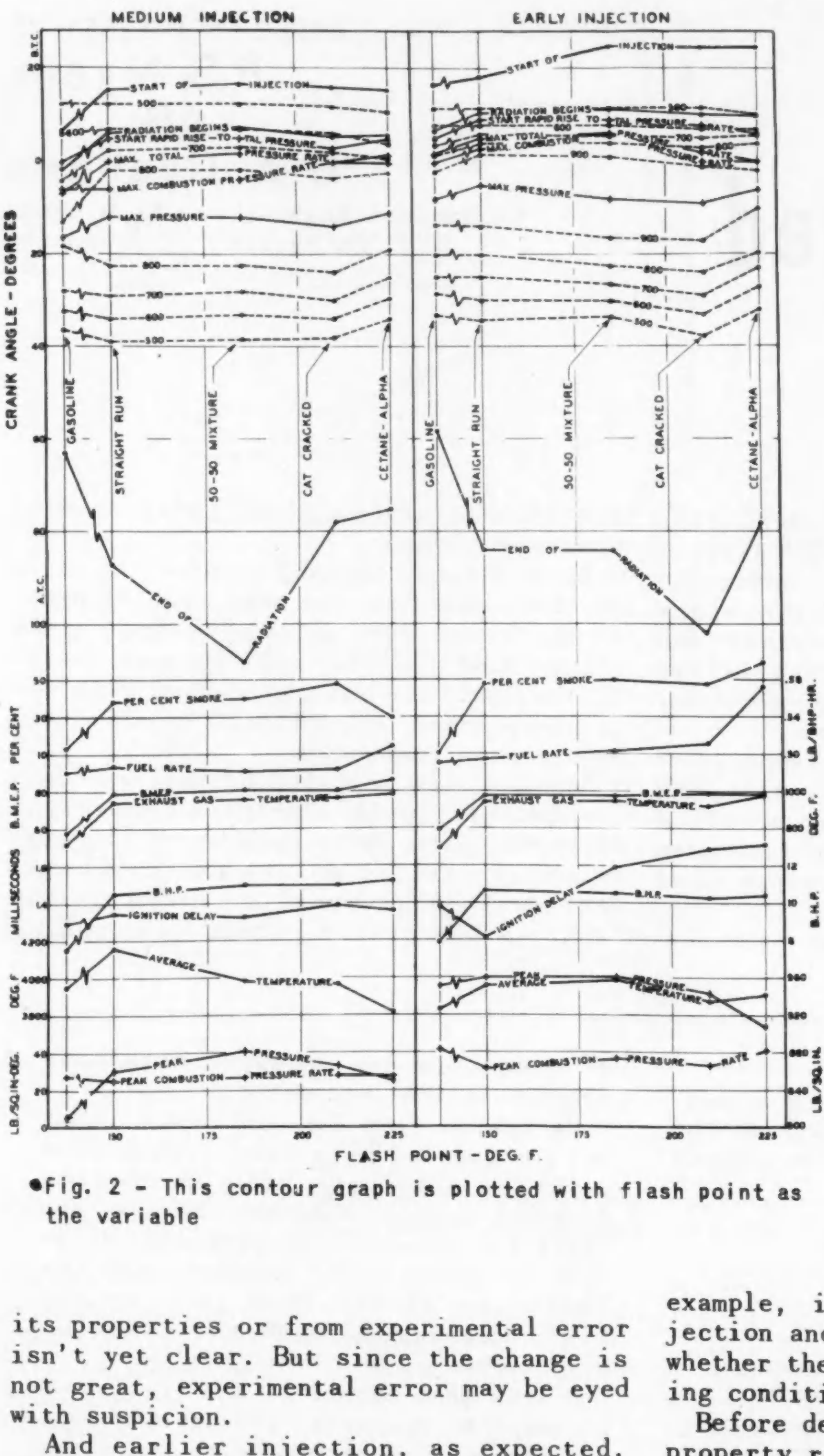
### Combustion Temperature Gage

Combustion flame temperatures of the diesel fuels tested at the University of Wisconsin are measured with this electro-optical pyrometer.




Radiation from the combustion chamber is focused by a lens system on a limiting diaphragm with an opening somewhat smaller than the image at the radiation source. This prevents vibration or other small movements at the radiation source from varying the light passing through the limiting diaphragm.

A lens then parallels the light, two prisms next disperse, and another lens refocuses it. A barrier with two slits is placed at the focal point of this lens. Phototubes behind each slit are actuated by radiation passing through it. After going through a series of amplifiers, the light is translated into reading of true flame temperature on the cathode ray tube of an oscillograph.




•Fig. 2 - This contour graph is plotted with flash point as the variable

its properties or from experimental error isn't yet clear. But since the change is not great, experimental error may be eyed with suspicion.

And earlier injection, as expected, gave higher total rate of pressure change due to combustion in all cases. But extent of this change at two different points varied between the different fuels. The gasoline mixture, for example, showed a greater increase (in rate of pressure change due to combustion) with earlier injection than other fuels.

Probably the most consistent trend found is shown in the contour graph, Fig. 2, plotted with flash point as the variable. (No value is given for gasoline since its flash point had not been determined.) But even here there are inconsistencies, so that valid correlation with flash point is not a certainty.

Presence of variables other than fuel composition complicates analysis of this and other contour graphs plotted. For example, if you vary both point of injection and the fuel, it is hard to tell whether the fuel or the change in operating conditions produced the effect noted.

Before developing specific performance-property relationships, we will have to get accurate combustion data for many more fuels under greatly varying engine operating conditions. But these preliminary studies have yielded clues to more profitable future investigations.

Complete copies of papers on which this article is based are available from SAE Special Publications Department. Price: 25¢ each to members, 50¢ to nonmembers.

# Automotive Designer's Concept of Steel vs Light Metal

BASED ON PAPER* BY

D. F. Toot
Project Engineer
Chrysler Corp.

BASIC factors in designing aluminum and its alloys for automobiles are cost and ease of manufacture.

In automotive design these factors must always be kept in mind because parts must be built as easily and cheaply as possible.

But if the designer finds a part will function better if made of aluminum, he should do everything to overcome objections based upon cost or difficulty of production.

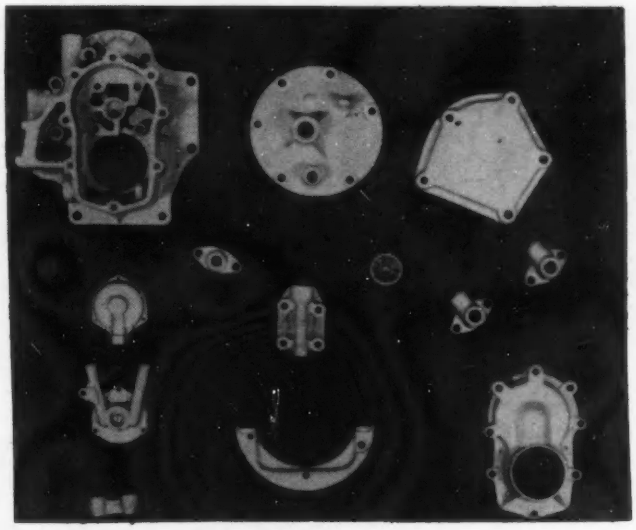
During the war, production men reached new heights of achievement, and now can build of aluminum practically any part designed. The cost may be sky-high, but improved methods eventually may bring it down.

Here is how properties of aluminum, steel and cast iron affect a designer's work:

*Yield Strength.* In designing a load-carrying part, one should first check a number of critical points to determine the cross section to assure against failure of the part. In most cases, this means that the yield strength of the material must not be exceeded, because a bent part usually has lost its functional ability.

Yield strength of both mild steel and unheat-treated wrought aluminum varies considerably with the amount of cold-working before or during fabrication. That of cold rolled steel is about 100% greater than that of fully annealed steel of the same analysis.

An increase in yield is effected by cold forming to a less degree. This improvement is seldom utilized because the amount of cold working varies considerably and only in the region of sharp bends is anywhere near 100% obtained. Parts which are to undergo considerable forming have proved to be satisfactory by experimental testing when made of a lighter gauge than a



●Die cast aluminum alloy parts now in production

*Paper "An Automotive Designer's Concept of Steel vs. Light Metals" was presented at the SAE Summer Meeting, French Lick, Ind., June 7, 1948.

theoretical stress analysis would indicate.

Variation in yield strength of unheat-treated wrought aluminum due to cold working may be 350 to 400% between dead soft and full hard. This is too great a difference to be ignored, as it often is in steel stampings.

By paying attention to the depth of draw and bend radius, ¼ or ½ hard blanks can be used and the yield strength of the part will be only slightly less hard than steel's. An increase of from 10 to 15% in gage of aluminum for such a part should suffice.

When designing parts where severe draws or sharp corners are unavoidable and dead soft sheet must be used, the yield strength will remain low in those portions where little cold working has occurred. If the unworked portions are stressed, the aluminum may have to be twice as thick as steel in order to have comparable strength. Experimental aluminum alloy fenders required material 40% thicker than for steel fenders. Stones striking the unworked portion dented the fender.

With changes in forming operations and possible local annealing, use of a higher temper aluminum would make a successful fender with equal thickness.

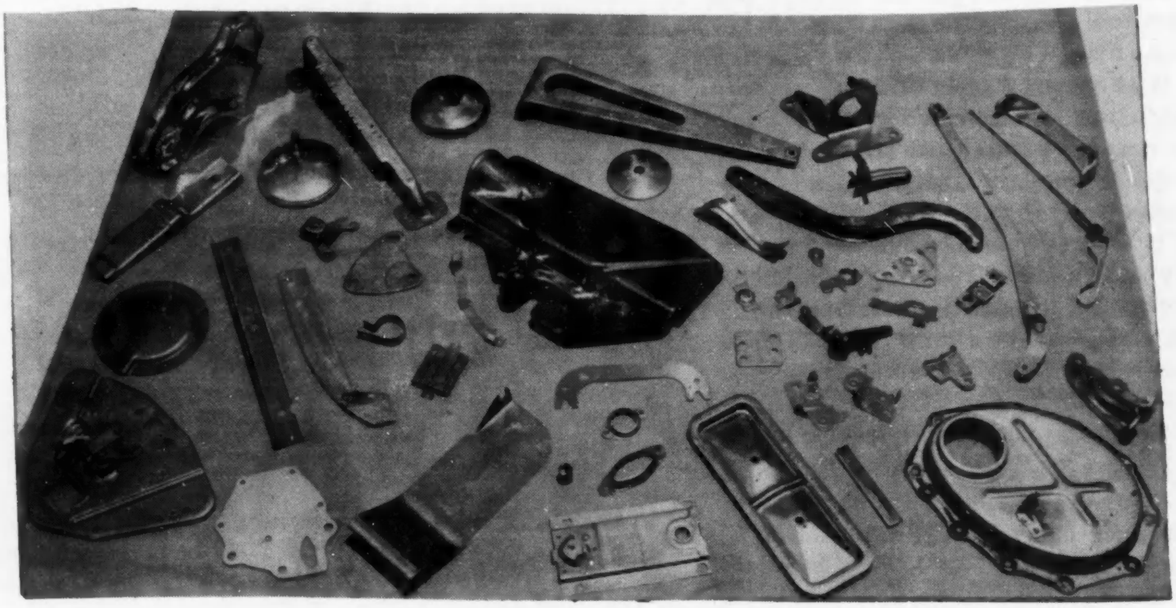
Unheat-treated aluminum sand castings in general have a yield strength about 50% as high as that of "run of the mine" 20,000 to 30,000 psi iron castings. Stressed aluminum sections would have to be about 45% thicker than corresponding iron sections. However, many of our iron castings are thicker than necessary in order to take care of core shifting, metal flow, and so forth.

As far as static strength is concerned, 80% of the sections would not have to be increased if made of aluminum. There are cast irons whose strength is much more than 30,000 psi. We must resort to heat treated permanent mold castings or increase the sections proportionately larger than indicated if we are to substitute aluminum for iron in such parts.

Because yield strength of aluminum alloy die castings is about 25% less than that of gray iron, this difference could be corrected by increasing the section by about 15%.

Die castings can be made with so much thinner sections than is possible with gray iron. Hence for static strength, many sections of the die casting could be made much thinner than the corresponding iron sections. More ribs and more complicated rib patterns can be used in die-casting, making it possible to reduce some sections which, in cast iron, are rather highly stressed. With present equipment and techniques, porosity of aluminum die castings can be controlled closely except in such spots as heavy bosses.

•Some experimental aluminum alloy automotive parts



Successful outboard engines have been made almost entirely of die castings, including the pistons, connecting rods, and the cylinder block. The latter are cast with steel liners.

Aged, but unheat-treated, permanent-mold aluminum alloy castings have yield strength probably 10% higher than the strength of 20,000 to 30,000 psi gray iron. Thinning of sections of the aluminum casting in places where the iron section is determined by foundry practice and those heavier sections designed to carry load, is indicated.

*Strength at Elevated Temperatures.* Few parts of the engine, fluid couplings, and torque converters reach temperatures which appreciably reduce the yield strength of aluminum. At 300 F most aluminum alloys will have a yield strength about 10 to 50% lower than that at room temperature.

Stressed parts to be exposed to relatively high temperatures require particular care in choosing the proper alloy. Strength of steel is affected by high temperatures. Oil-hardened springs lose strength rapidly above 400 F but ordinary steel parts are little affected below 500 or 600 F.

Static overload failure is rare. It is much more important for a part to be able to withstand often repeated loads considerably less than maximum. Comparison of endurance limits for steel and aluminum gives a truer picture of the relative strength than comparison of their yield strengths.

*Endurance Limits.* Unheat-treated wrought aluminum endurance varies from somewhat less than half to about three-quarters that of hot rolled SAE 1010 carbon steel, depending upon which alloy is used.

To make up this difference in endurance limit to give an aluminum part equal fatigue life to a similar mild steel part, its thickness should be increased by 45%.

Sand and permanent mold cast aluminum endurance limits are less than half that of cast iron, and equivalent aluminum sections should be about 50% greater except where the latter are thicker than necessary because of foundry limitations.

But die cast aluminum has an endurance limit equal to or slightly higher than our ordinary automotive cast iron. However, die cast aluminum, unlike cast iron or sand cast aluminum, is notch-sensitive.

It is believed that this notch-sensitivity exists only when the chilled surface layer has been broken. At those points in a die casting where, due to machining operations, the skin is broken, a stress concentration problem may arise.

Any advantage held by aluminum over cast iron may be more than wiped out. In designing die castings, one must keep this stress concentration in mind, whereas in sand castings of either aluminum or cast iron, this is no problem.

In most cases, ribs and turned up flanges are added to give rigidity to a structure. One should proportion them to increase, and not reduce, the strength of the section to be stiffened. A section two inches wide and an inch deep, with a rib a quarter of an inch wide and one inch high, is about two and a half times as stiff, but only 90% as strong, as if the ribs were omitted.

Such weakenings are particularly noticeable in fatigue loading. With aluminum, in which the ratio of endurance limit to yield strength is lower than in steel, proper rib proportioning is extremely important.

*Modulus of Elasticity.* In a number of automotive parts stiffness is more of a problem than strength. Transmission cases, linkages, and brake parts receive close scrutiny for deflection.

Aluminum's modulus of elasticity is only one-third that of steel. Strength deficiencies can be circumvented by using heat-treatable alloys if the extra operations are warranted. There seems no way of getting around a low modulus of elasticity. Therefore, when an aluminum part may not deflect further than its steel counterpart, the depth of section must be increased 45%.

Aluminum castings show a much better comparison to gray iron than wrought aluminum does to steel. Cast aluminum's modulus of elasticity is about three-fourths that of cast iron's value. This suggests increasing the depth of the aluminum section 10%. Variations in the value of the modulus of elasticity of cast iron are wide. Curves range in values from 8,000,000 to 20,000,000 psi, depending upon various factors. I use 14,000,000.

*Thermal Expansion.* Some of the engine, transmission, and fluid coupling parts

are subject to wide nature changes. Aluminum's coefficient of thermal expansion is about twice steel's.

When aluminum parts are fastened with steel bolts, thermal stressing beyond the yield strength loosens connection at lower temperatures. Steel inserts in aluminum castings are liable to be loose in some temperature range. Running fits of steel parts mounted in aluminum cases will be seriously affected by temperature, and careful investigation before designing is essential.

*Galvanic Corrosion.* When two dissimilar metals are immersed in a salt solution the difference in electrical potential causes a current to flow between them. This accelerates corrosive action.

Aluminum and steel joints exposed to the salt water from winter streets corrode rapidly, particularly if they hold this moisture for a while. Such bimetallic joints must be insulated from the salt or from each other. Engine coolant poses this problem.

*Hardness.* Brinell value of unheat-treated aluminum alloys, roughly one-third that of mild steel, will affect moving parts such as levers and other linkages exposed to the weather, mud, and sand. They do not resist wear even when made of steel.

If made of aluminum, these parts must be made with hardened steel inserts.

Anodizing is not effective except where lubrication is plentiful, as in pistons. It does not stand up to severe abrasive wear. Threaded holes require steel inserts if the screws are to be removed more than three times in service.

Aluminum's softness raises a question in its use for exterior parts. It would seem that chrome plating such parts would protect the material despite its softness.

As a bearing material, aluminum has proved to be successful with hardened steel shafts.

*Solder.* Automobile bodies have reached their enviable state largely because we stamp panels and spot weld them. Welds are in a depression which is later filled with solder, and joints are invisible.

At the present state of the art, weld depressions of aluminum sections cannot be soldered. A satisfactory filler or a different type of aluminum joint design would solve this.

*Weight.* Its light weight makes use of aluminum attractive. If, instead of following conventional design of sections, they were U or box shaped, and outside dimensions were adhered to, the increase in volume of aluminum over steel would be considerably more than I have indicated. For example:

Increasing thickness of a plate by 10% results in a 21% increase in bending strength. But to increase bending strength of a 2 in. x 2 in. x 1.8 in. box section 21%, requires an increase of almost 25% wall thickness. The total number of parts which could be changed from steel or cast iron to aluminum would contain 45% more volume of material. Hence weight saving would be one-half instead of two-thirds.

A gross weight reduction of our automobiles by 10% would permit:

A smaller engine,

Perhaps a simpler transmission or faster rear axle and smaller brakes,

Reduction size of suspension units, including wheels and tires,

Weight saving pyramids. The customer would save a little in his license plate cost in some states, and would use less fuel.

*Cost.* A 50% weight saving means that, assuming all other operations to be the same, aluminum parts would be practical if they did not cost more than twice as much per pound as corresponding steel or cast iron parts. To date, this has not been the case, but this price situation can change overnight. We are finding more parts daily which are economical at today's price of aluminum.

Cast iron parts which carry practically no load are generally a lot heavier than their function requires. These could be replaced with thin walled die castings whose weight might be only one-fifth that of the iron parts, thus allowing a pound price of aluminum five times as great as iron.

Cost of processing the basic metal is much less in die casting, or partially automatic permanent mold casting, than with sand casting.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# How to Get More Btu's Out of Our Fuel

BASED ON PAPER* BY **W. G. Perriguey** Esso Standard Oil Co.

THE problem of getting more out of a barrel of crude oil resolves itself into two parts: getting more automotive fuel of better quality out of the crude, and getting more Btu's out of the fuel in terms of engine performance - a job primarily for the engine designer, who must, however, look to the petroleum engineer to provide a fuel that will take full advantage of any improvements in engine design that he makes.

In the past the first method was used most successfully, but it has just about been worked to the limit. At least for the immediate future, any expansion in quantity of automotive fuel produced from a given barrel of crude must be at the expense of products, such as heating oil, the demand for which has grown more rapidly in the past few years than has the demand for automotive fuels.

## HIGHER COMPRESSION PRESSURES

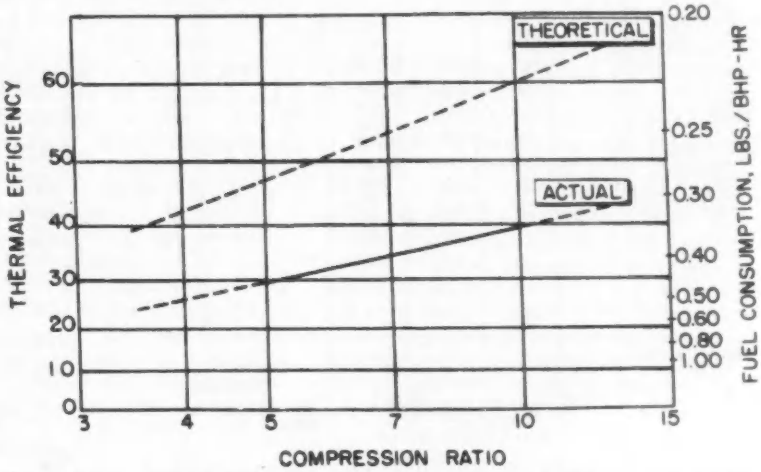
One of the most important means of increasing the thermal efficiency of the spark-ignition engine is to have the gas in the combustion chamber more highly compressed at the time of ignition, thus allowing a greater expansion to take place. Two methods of attaining this higher compression are available: increasing compression ratio and the use of supercharging.

The former method has been well explored by Kettering,[1] who described an engine with a 12½:1 compression ratio. When installed in a car, a 40% improvement in mpg is claimed for this engine, as compared with an engine of 6.4:1 giving the same vehicle performance.

The increase in thermal efficiency with higher compression ratios is shown in Fig. 1. The curve marked "actual" takes

[1] See SAE *Quarterly* Transactions, Vol. 1, October, 1947, pp. 669-679; "More Efficient Utilization of Fuels," by C. F. Kettering.

*Paper "Automotive Fuels" was presented at a meeting of the Williamsport Group of the SAE, Williamsport, Pa., March 1, 1948.




• Fig. 1 - Variation of thermal efficiency with compression ratio

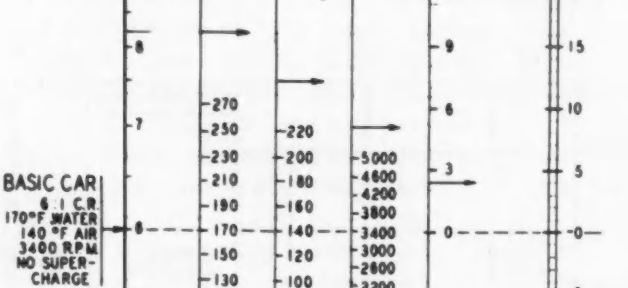
into consideration valve time lag, and the like. Note that a compression ratio of 5:1 gives a thermal efficiency of 30%; but a compression ratio of 10:1 raises this efficiency to 40% - a one-third increase in thermal efficiency. In terms of fuel consumption, this means a decrease from 0.45 lb per bhp-hr to 0.35 lb per bhp-hr.

Unfortunately, both methods of increasing compression pressure require a fuel of higher octane number, for the more compressed the charge the greater will be the tendency for detonation to occur. In fact, the octane-number requirements of the 12½:1 engine just described are so high that it will not operate satisfactorily on any of the automotive gasolines on the market today.

Fig. 2 shows the factors influencing octane-number requirements. A basic car is assumed that has a compression ratio of 6:1, a water temperature of 170 F, an underhood air temperature of 140 F, and a speed of 3400 rpm.

This figure shows that an increase in compression ratio from 6:1 to 7:1 increases the octane requirement of the engine about 8 points.

If, on the other hand, we increase the cooling water temperature from 170 F to 190 F, the octane requirement is increased by 2 points.




• Fig. 2 - Factors influencing octane-number requirements of engine

Likewise, if we increase the underhood air temperature from 140 F to, for example, 200 F, we make it necessary to have a gasoline of 6 octane numbers higher. On the other hand, if we decrease the underhood temperature from 140 F to 100 F, we decrease the octane-number requirement by 4. If engine speed is increased, say, from 3400 rpm to 4600, we increase the octane requirement of the engine by 5 points.

If two or more factors are changed at the same time, the total change in octane requirement can be obtained by adding the increase (or subtracting the decrease) in the requirements of the various items. Thus, if the compression ratio is increased from 6:1 to 7:1 and, at the same time, the water temperature is increased from 170 F to 190 F, the increase in octane requirement is 8 + 2 or 10 points.

Fig. 2 also shows the effect of supercharging. If we add a supercharger to this basic car that supercharges to 3 in. of Hg, the octane-number required is 5 points more.

Improper spark advance and carburetion also adversely affect the knockfree performance of an engine. Field surveys show that a fairly high percentage of the vehicles on the road are suffering from poor engine performance because of faulty adjustment. This is, of course, less true of commercial vehicles than passenger cars because of much better maintenance supervision in fleets. Some fleets have, however, a tendency to advance the spark timing beyond the point of maximum power in an effort to increase power.

If the gasoline being used is of such quality that knocking does not occur when the spark advance is set at maximum power, timing cannot be satisfactorily adjusted by advancing the spark until knocking occurs. The result will most surely be to pass the point of maximum power and end with poorer efficiency. In such cases, unless a chassis dynamometer is available, the spark should not be advanced beyond the manufacturer's recommendation.

Complete paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

# Gas Turbine Seen Powering Vehicles

Based on paper by

FRANK L. SCHWARTZ

University of Michigan

THE gas turbine holds much appeal as a motor vehicle powerplant because of its good torque characteristics, simplicity, low first cost (when fully developed), elimination of the conventional cooling system, and lowered maintenance. But its acceptance for highway transportation depends on both the future fuel situation and progress in developing more efficient compressors and turbines.

Configuration best adaptable to vehicle propulsion seems to be the dual cycle. This calls for two turbines - one for driving the compressor and one for supplying external power. The power turbine, being independent of the compressor turbine, can run at any speed from zero to maximum - always being supplied with air from the compressor turbine.

This arrangement gives flexibility for vehicle use. Gas from a single combustion chamber may pass through the two turbines in series, or a second combustion chamber may be interposed between the two turbines.

The dual-cycle gas turbine holds many advantages over the reciprocating engine. A separate turbine can be geared to the driving axle. The compressor and compressor turbine could be conveniently built to suit body design, but should be placed close to the driving axle.

The separate compressor turbine could run at nearly constant speed (at optimum efficiency), yet the power turbine could fluctuate from zero to maximum speed. A minimum of inertia would be directly coupled to the axle.

The gas turbine would occupy only two-thirds the volume of an equivalent reciprocating engine; or, it could develop more power in the same space. It would also weigh less and require no cooling, saving fan horsepower consumed and eliminating the radiator.

And the gas turbine needs little lubrication. It consumes less than 4% of the lubricating oil required by a diesel engine. Only parts needing lubrication are ball or roller bearings on the compressor and turbine shaft.

The dual gas turbine has not only smooth torque, but a very desirable torque characteristic. The engine itself produces nearly constant torque with speed variation. To provide adequate torque for rapid acceleration and hill climbing, two other gear ratios can be used. The torque curve envelope would form a hyperbola of constant horsepower with ideal transmission.

## GOOD DESIGN RPM IS 0.7 RUNAWAY

The power turbine yields maximum efficiency and power at speeds of about half the runaway speed. But designing the turbine to get desired torque at about 70% of the runaway speed maintains a high efficiency over 30 to 70% of runaway speed, or 50 to 100% of vehicle speed.

Even more important is improvement in torque characteristic. Moving the design point to 70% of runaway speed nets a stall torque four times the running torque at maximum speed. Except for speeds below 30 mph, the gas turbine is superior to multiple gear transmission. Raising combustion chamber temperature will improve low-speed torque for short periods.

Turbine speed at maximum road speed could be set at 20,000 to 30,000 rpm with a set of planetary gears required. Another gear would handle the reversing job. Control of the simple turbine need consist of only a throttle valve on the fuel line to govern combustion temperature.

Gas turbines are not temperamental about the fuels they burn. Poor quality fuel oils burn successfully, even lower in quality than diesel fuel. Bunker C fuel already has been used. And much development work is under way with powdered coal.

The gas turbine's specific fuel consumption at full load, with a 1600F combustion temperature would be about 0.65 lb per hp-hr, rising to 0.90 lb per hp-hr at half load.

Fuel consumption is the principal disadvantage of a gas turbine without regeneration, particularly at part load. But its use of lower quality fuel and small lubricating oil needs make its fuel costs competitive with diesel and spark ignition engines.

The fuel situation will have much to do with the gas turbine's future. With the present price differential between furnace oil and diesel oil plus diesel lubrication cost (figured at 10% of diesel fuel cost), a gas turbine with 24% efficiency costs as much to operate as a 36% efficient diesel. And first cost of the gas turbine should run about 75% of the diesel engine.

Automotive engineers will watch future developments with interest. Better high temperature alloys, more efficient compressors and turbines, powdered coal, cooled blades, and improved manufacturing methods will determine when and to what extent gas turbines will operate on the highway.

# Diagnoses Design Defects Of Plane Engine Controls

Based on paper by

HARRY W. NEVIN, JR.

United Air Lines, Inc.

WEAR and vibration make up the biggest nemesis of mechanical and electrical aircraft powerplant controls. Many control components have a service life shorter than the period between plane overhaul.

From a maintenance standpoint, present cable type controls still require too many man-hours for rigging and maintenance. Wear on some cables, pulleys, and fairleads takes a lot of maintenance replacement by airline operators. Pulleys used as guides on straight cables with small wrap angles are subjected to pounding and wear by vibrating cables. This pounding produces flat spots on pulleys and damages pulley bearings so that they cock.

On one type airplane it has been necessary to replace the

engine section propeller governor cable, pulley and fairlead about every 500 hr because of vibration damage; yet cables in the airplane structure seldom have to be replaced before the 8000-hr inspection. This trouble now is being corrected.

Cables wear from pounding or abrasion on pulleys and fairleads. Since abrasion increases because of dirt adhering to oil-covered cables, pulley and fairlead cable locations should be shielded from oil and dirt.

ELECTRICAL CONTROLS SHORT-LIVED

Powerplant vibration plays havoc with present electrical controls from the maintenance man's standpoint. For example, on one type airplane several failures of the propeller governor lead stemmed from chafing of the outside glass covering of the wire and grounding of it against the conduit in the engine section. In this case similar failures are being prevented by changing the glass wiring covering to cloth.

In another case, an electrical supercharger clutch shift actuator, mounted on the engine, operated erratically or failed because of loose electrical connector inserts and broken wires. This prevented clutch shifting, or produced an even more serious condition due to intermittent contact of the broken wires. It gave rise to creeping of the clutch selector valve, causing slippage and burning of the supercharger clutches in the engine.

And broken wires in the engine-mounted tachometer generator have caused loss or regulation of engine speed in an electronic propeller synchronizer system.

In electronic control development, efforts should be directed toward simplifying circuits. This will not only reduce the quantity of items that can fail, but it will simplify trouble shooting and maintenance. Any complex electronic unit should be separated into several components, each of which is simple to check for operation and easy to replace if faulty, without disturbing the other components.

Breaking an assembly down into interchangeable components saves the operator money since it reduces his capital investment in spare parts. Yet if a faulty unit cannot easily be located by a mechanic at a line station, flight delays will follow if the mechanic changes the wrong unit. Flight delays can quickly offset any economic advantages gained by this line of thought.

Many of these short-lived powerplant control components are considered adequately tested and serviceable by the manufacturer. Perhaps manufacturers should test all new type engine control components under more severe vibration conditions and over longer periods to better simulate actual flight conditions. (Paper "Air Transport Maintenance and Engineering Aspects of Powerplant Controls," was presented at SAE National Aeronautic and Air Transport Meeting, New York, April 13, 1948. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

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## Calls T-Rules Unfair To Commercial Planes

Based on paper by

F. W. KOLK

and R. W. AYER

American Airlines, Inc.

RESTRICTIVE take-off requirements in the Civil Air Transport Category Performance Regulations jeopardize the economy of current airplanes.

Flap settings are a case in point. Partial engine considerations lead to flap settings of about 5 deg to fly maximum weight from a given runway. But under average conditions, take-off is shorter and altitude at end of field greater with a 15-deg flap setting. With the 15-deg setting, a pilot experiencing a sudden engine failure at the end of the runway (when he's several hundred feet in the air) is in a much safer position than if he had set his flaps at 5 deg.

The overall problem becomes somewhat clearer by referring to Fig. 1. This diagram shows a series of take-offs on a distance and time scale.

Present regulations require that, at some critical speed $V_1$, the pilot either stop within bounds of the runway or continue his take-off. Let's call the corresponding time $T_1$. If the engine fails before $T_1$, the pilot can stop; if it fails after, he can continue. In this case his flight path is shown by "one engine CAR take-off." His flight path is "two engine take-off" if he doesn't experience failure.

Here's where the regulatory concept is fallacious: Fig. 1 shows us that $T_1$ corresponding

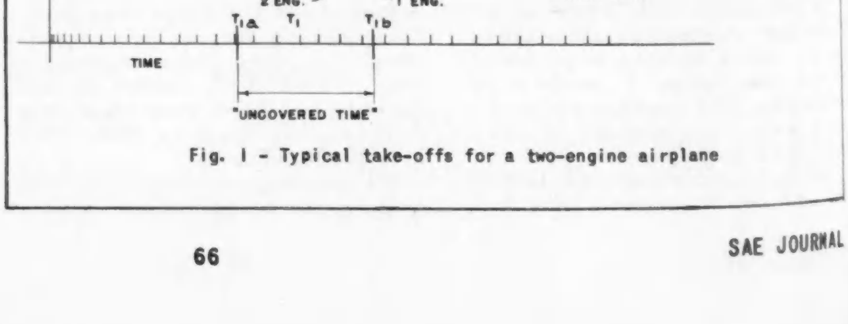



Fig. 1 - Typical take-offs for a two-engine airplane

to $V_1$ represents a point. Thus the time within which the pilot has a choice is infinitesimally small. Probability of a sudden power failure at $V_1$ is zero. And even assuming ever-present probability of failure on any flight, we can still tolerate a definite time interval corresponding to the point $T_1$. And during this period chances of power failure are remote to the point of being almost impossible.

What's needed is a finite time interval with probability of no engine failure during this time block. Experience with power failure rates serves as a basis for calculating this value.

For two-engine airplanes, 5 sec of uncovered time between $T_{1a}$ and $T_{1b}$ seems appropriate. To be consistent, a four-engine airplane can tolerate only a 2 1/2 sec period.

The DC-3, which never heard of T-category, has violated this take-off rule for many years with no record of an accident due to this procedure. The DC-3 operates with an uncovered time of from 5 to 10 sec.

Trouble with the T-category take-off rule is that it doesn't recognize characteristics of the airplane in both normal and emergency take-off. It unduly penalizes two-engine airplanes and may be excessively liberal with four-engine ones.

Unnecessary restrictions also apply to requirements for rate of climb, terrain clearance, and length compensations for icy runways. Airline operators would like to work under revised regulations which are arbitrary only in basic essentials - such as ability to maneuver safely under emergency conditions and ability to clear obstacles after engine failures.

They object to having good airplanes damned because of high wing loading. There is little doubt that advanced, high-speed equipment, such as jet transports, cannot operate successfully and economically under the present regulations. The T-category doesn't give operators the flexibility of taking the most performance and economy from any airplane safely. (Paper "The Fallacy of Arbitrary Performance Regulations," was presented at SAE National Aeronautic and Air Transport Meeting, New York, April 15, 1948. This complete paper is available in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Tells How To Up Temperature Of Vehicle Cooling Systems

Based on paper by

F. M. YOUNG

Young Radiator Co.

(This paper will be printed in full in SAE Quarterly Transactions)

THERE are two ways of boosting jacket water temperatures above the 140-180F range to reduce size and cost of motor vehicle cooling systems: (1) with higher boiling point coolants and (2) with a sealed cooling system.

Boiling point of water - 212F - limits the temperature of the open forced-water system. We can climb above this ceiling with a higher boiling point coolant and by raising the thermostat's control temperature. Only high boiling point chemical meeting most coolant requirements - such as low cost, freezing point, commercial availability, toxicity, fire hazard, and corrosivity - is ethylene glycol.

Although it has a 388F boiling point, heat dissipation might decrease as much as 35% because of its comparatively low specific heat, thermal conductivity, and film coefficient. And hot spots also could be expected in the average engine. What we really need is a fluid with high boiling point, low freezing point, and all the other properties of water.

If we must stick with water, the sealed or pressurized cooling system is another way of raising cooling system temperature. The sealed cooling cap is shown in Fig. 1. It's been known for many years. These caps consist of two spring valves. One blows off to the atmosphere and protects the radiator by relieving at the system design pressure; the other spring relieves to the interior of the radiator and opens when a partial vacuum is created within the radiator after engine shutdown. The blowoff valve also permits the original expansion of water and relieves any entrained air.

To attain the 300F level would require a 57-psi cap for water including an extra 5 psi to protect against possible vapor and surge losses. The basic automotive radiator would have to be of the fin and tube type with heavy gage ribbed and reinforced tanks to withstand this pressure. Soft solders lose about 50% of their strength in shear and tension at 250F.

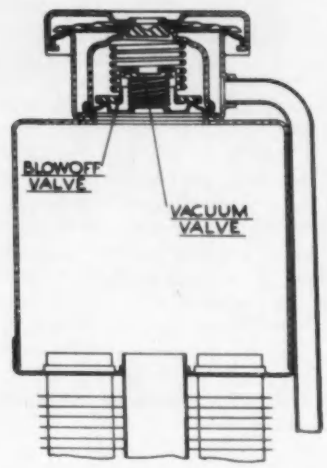


Fig. 1 - Typical cap for sealed cooling systems

Diffusion also occurs between tin alloy solders and copper at continuous temperatures above 250F so that bonding strength decreases. This calls for brazed or silver soldered construction in a 300F radiator. Probably the extra costs in manufacturing such a radiator would offset gains in reduction of heat transfer surface and fan horsepower. Staying with the economical soft-solder radiator restricts temperatures to 250F. This requires pressurization to 15 psi for water. Adding 3 psi for surge protection points to an 18-psi cap.

Required radiator surface can be decreased 60 to 70% by raising jacket water temperature to 250F (for constant engine heat rejection at 160F average jacket water temperature and 100F ambient air temperature). Specific reduction will depend on whether the decrease is taken in face area, depth of core, or a combination of both.

Required airflow decreases in relation to radiator proportions. Fan horsepower will be reduced 30 to 60%, depending how the changes are made.

Antifreeze solutions must also be considered. Fig. 2 compares curves of pressure cap setting versus boiling point for water and solutions of ethylene glycol and alcohol with a -20F freezing point.

At 15 psi, boiling point of the 44% glycol solution is 250F. This

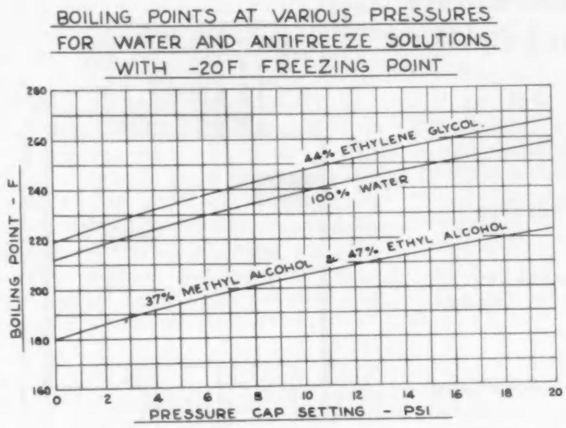



**Fig. 2 - Pressure-temperature relation of water and antifreeze solutions, with -20F freezing point, for sealed cooling**

concentration should decrease heat transfer by not more than 10%, because of high water jacket and radiator velocities.

Boiling point of the 37% methyl alcohol-water solution and of the 47% ethyl-alcohol-water solution at 15 psi is 215F. If alcohols must be used, this temperature still makes for a 40 to 50% cooling surface decrease and a 20 to 40% reduction in fan cooling input. (Paper "High Temperature Cooling Systems," was presented at SAE National Transportation Meeting, Philadelphia, April 1, 1948, and at the SAE Cleveland Section, April 12, 1948, and the paper "Developments in Engine Cooling Systems," presented at various SAE sections during November, 1947. These papers are available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ each to members, 50¢ each to nonmembers.)

## Oil Tests Warn Of Engine Woes

Based on paper by

RALPH L. FABER

Faber Laboratories

CRANKCASE oil analysis forecasts vehicle engine troubles before they erupt into costly repair jobs. This series of tests also points to economies such as maximum mileage before oil change.

The complete analysis consists of the following tests:

1. Solids Volume - determines whether oil's detergent or dispersive characteristics remain.

2. Faber Viscosity - a specialized viscosity determination adaptable to mass production techniques with good accuracy and good correlation with operating viscosities.

3. Foreign Matter - quantitatively grades all contaminants ordinarily found in oil. In the analysis report is indicated where metal found comes from (bearings, rings, or wall) and where gums, residues, and sludges are derived. Sources of other materials also are given.

4. Crankcase Operating Temperature - gives an estimation of general average temperature at which oil in the crankcase is held by the cooling system, ambient temperature, and operating conditions.

5. Type Of Dilution - determines, by examination of distillates, whether the dilutant consists of heavy ends (which steadily accumulate in the crankcase because of blowby or bad rings) or light fractions (that may come from over-choking).

6. Sludge Index - is based on a volumetric measurement of the initial oxidation and polymerization products formed as colloidal particles. They escaped detection until recently because of their small size and a density not much greater than the oil's.

By considering all these tests together, important causes of controllable operating faults usually become apparent. For example, take the following set of conditions: (1) the oil abnormally thickens during a given period of service; (2) the Sludge Index gives evidence of considerable oil oxidation; (3) but there is no sign of localized high temperatures such as excessive ring and wall wear or carbon from the underside of the piston heads.

### TROUBLES DIAGNOSED

It's a good bet that in this case the engine is either overloaded or under cooled.

But this same evidence of oil oxidation, accompanied by no unusual increase in viscosity and severe localized operating temperatures, points to poor adjustment. Late timing and lean carburetion are the most frequent causes.

From an overall evaluation also generally emerges the cause of excessive sludge in the crankcase, valve chambers, and other portions of the engine. If the Sludge Index and solids volume both are high, and at the same time excessive water or emulsion appears or traces recur, it is usually a good sign that cold temperature operation is the source of trouble.

Remedy for this involves merely changing operating temperatures or either insulating or ventilating that portion responsible for the sludge.

Tip-off to high temperature sludge (which consists of resins, varnishes, or lacquers) is a high Sludge Index and high Solids Volume together with other evidence of high temperature operation. (Clues to the high temperature condition are thickened viscosity and frequent signs of carbon deposits forming)

### ANALYSIS DEFINES OIL LIFE

In addition to its role in preventive maintenance planning, this oil analysis system defines maximum safe use period for oil in each engine. No danger will come from continued use of the oil so long as: viscosity remains within safe limits; there is no danger of contamination; the oil has not deteriorated or does not contain deterioration products;

the oil retains its original detergent and dispersion properties. All these items are determinable from the tests, considered separately or in combination.

Schematic crankcase oil analysis and interpretation has been developed into a service. Operating personnel take samples at periodic intervals and send them to the laboratory for analysis and interpretations. A report with recommendations on corrective measures necessary is then furnished the operator. (Paper "Faber Engine Analysis for Internal Combustion Engines," was presented at the SAE Metropolitan Section, New York, Oct. 21, 1948.)

## Cost Records Gage Fleet Performance

Based on paper by

L. L. PERNOT

Four Wheel Drive Auto Co.

REALISTIC cost recording will guide the fleet operator to true maintenance and operating economies and also will tell him other things about his operation.

In the first place, the operator must recognize two categories of costs - those which vary directly with total miles traveled or total tons hauled and those which do not. From Fig. 1, which shows proportions of the various items of cost for a particular operation, we can segregate the items into the two classes.

The fixed costs - which remain constant regardless of total tonnage or mileage - consist of license fees, insurance, and depreciation. They total 16.9% of total operating costs. The remaining items are variable and have a direct bearing on maintenance.

Many operators not following such a record-keeping plan fall into pitfalls of false economies.

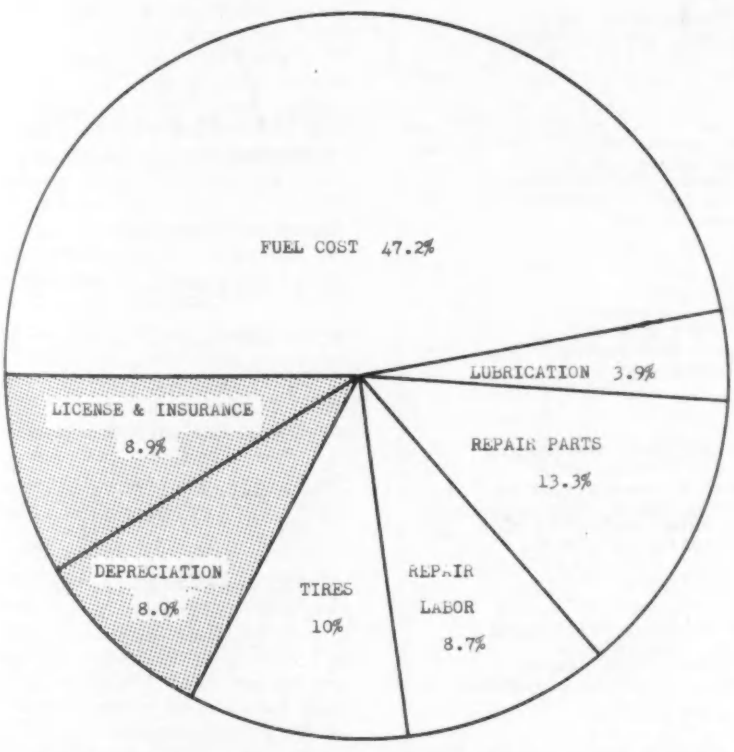



Fig. 1 - This kind of operating cost analysis should be made by every fleet. Fixed expenses are shown by the shaded area, others are variable expenses

For example, some fleet men think they are saving money by lubricating equipment with inferior grade oil or by extending the oil change period beyond the recommended time. Fig. 1 shows that lubricant cost - including motor oil and all other vehicle greases and lubricants - makes up only 3.9% of the total operating cost of a piece of equipment.

By violating good lubrication practice, the operator saves an insignificant amount at best. Many have found that the 1% economy they may net in this fashion is more than offset by the increased cost of repairs and repair labor. They actually make a dent in an item representing 22% of total operating cost, as shown for repair parts and labor in the chart.

A good maintenance program will go a long way toward reducing the different operating cost factors. Operating the engine more efficiently will reduce the big fuel cost item. This calls for checking the engine at certain intervals to keep parts such as spark plugs, distributor, and carburetor in proper working order and adjustment.

Operational cost records also can tell you something about your drivers. Take the case of two or more pieces of the same kind of equipment operated in the same fleet. Considerable difference between the cost of each unit points to differences in driving skill and care. (Paper "Running a Fleet of Trucks Without Cost Records Is Like Using a Clock Without Hands," was presented at SAE Oklahoma A & M Student Branch, March 13, 1948. This paper is available in full in mimeographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Friction Oxidation Plagues Oscillating Ball Bearings

Based on paper by

L. A. HILLES

Fafnir Bearing Co.

OSCILLATING action can accelerate ball bearing failure through friction oxidation, unless a bearing of suitable size is chosen.

Friction oxidation, the ordinary

mode of failure with bearing races in reversing applications, is a phenomenon where grease and race metal oxidize simultaneously. Metal thus removed from the race under the ball contact causes iron oxide (rouge) to mix with the grease. It forms a lapping compound that speeds deterioration.

Friction oxidation shortens bearing life as compared with normal fatigue-failure life for single direction motion.

Extensive research with different kinds of bearing designs and greases gave rise to a theory explaining this action. The culprit in this case was named "totalization of pressure per lubrication cycle." A high percentage of the contact ellipse area at point of reversal is stress-abused far more severely before being relubricated than in pure rotary motion.

At this point, totalization of pressure is doubled since this area is abused just after start of reversal, under almost starved lubrication. Even after uncovering of the loaded area permits free lubrication, lubrication is poorer than had the ball moved in that direction with pure rolling action.

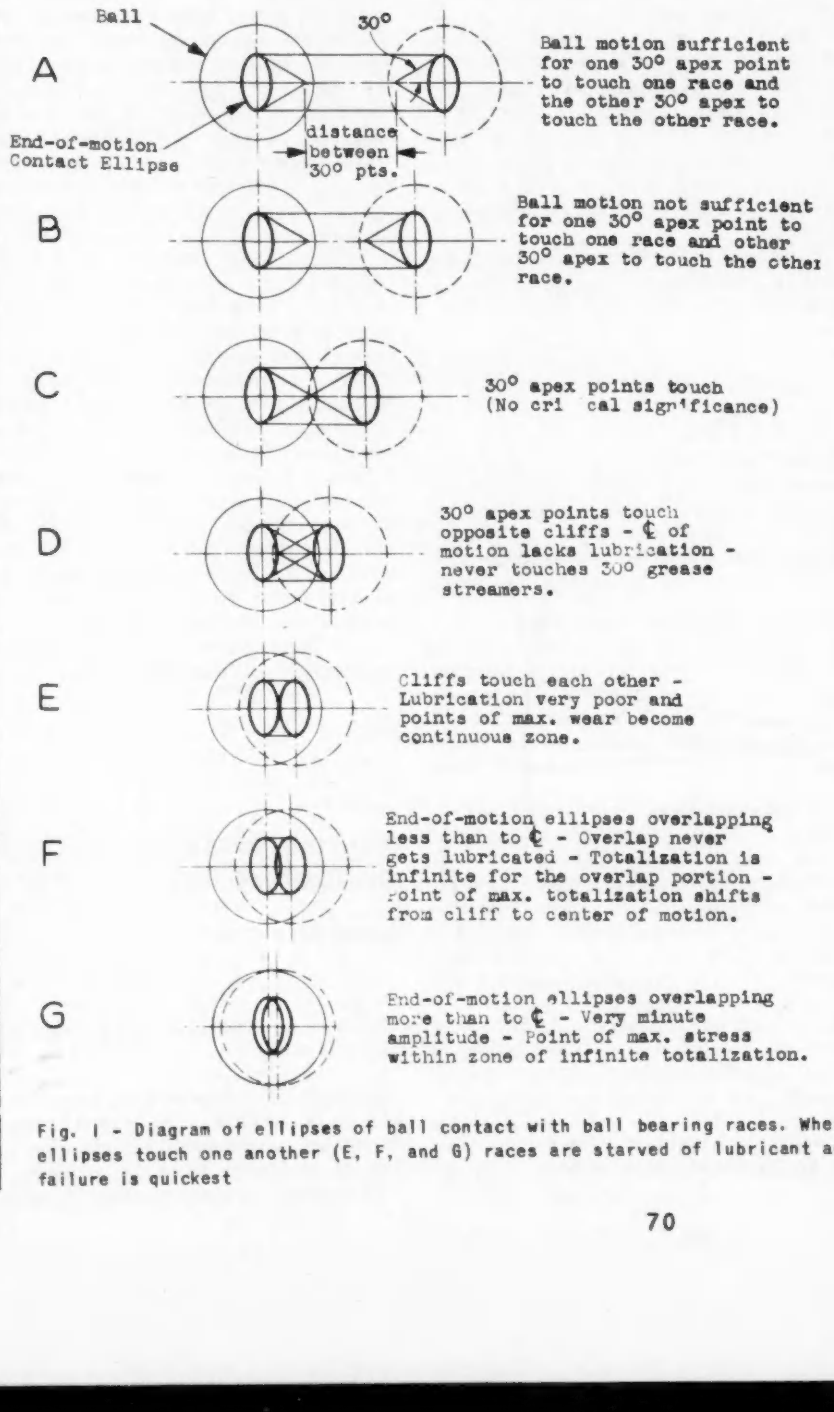



Fig. 1 - Diagram of ellipses of ball contact with ball bearing races. Where ellipses touch one another (E, F, and G) races are starved of lubricant and failure is quickest

Fig. 1 shows different oscillatory loading conditions. In "A" the balls move far enough to carry lubricant from first to second position and back. But where ellipses touch one another or overlap, the races remain dry - free from lubricant - and failure is swiftest.

The hazard ratio for oscillatory motion is so great, the theory proved, that for equal abuse at these critical points (where ellipses overlap) with rotational motion requires about a two-thirds load rating reduction.

To use the catalog rating correctly, first find the number of stress repetitions over a given point and determine speed of continuous rotation duplicating the stress repetition condition. Then reduce the rating at that speed to one-third its value.

An admittedly severe sacrifice in load rating, it must be so until some one can tell us how to overcome friction oxidation. (Paper "Bearings in Action - Plague of Friction Oxidation," was presented at SAE Philadelphia Helicopter Symposium, Dec. 10, 1947. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Safety Fuels Perform Satisfactorily in Tests

Excerpts from paper by


W. J. SWEENEY, J. F. KUNC, JR., W. C. HOWELL, JR. and O. G. LEWIS

Standard Oil Development Co.


(This paper will be printed in full in SAE Quarterly Transactions)

TESTS conducted to determine the knock-limited performance, specific fuel consumption, and oil dilution characteristics of low-volatility aviation safety-type fuels have shown that satisfactory engine operation at warmed-up conditions can be obtained with fuels of this type.

Multicylinder tests were run

in a Wright Cyclone R-1820-56 engine modified for direct cylinder fuel injection and compared with tests run in F-3, F-4, and C.U.T. engines.

The fuel ratings obtained in tests of the Wright engine and F-3 and F-4 engines are summarized in Table 1, where both lean-mixture and rich-mixture ratings are expressed in terms of A-N Performance Number. The full-scale engine lean ratings are those determined at the point on the mixture response curves where the minimum knock-limited power output is obtained for the fuel (approximately 0.065 fuel-air ratio), while the rich-mixture ratings are at both 0.09 and 0.10 ratios - the latter corresponding to the mixture strength normally used under take-off conditions with this engine.

The low-volatility fuels appeared to have somewhat flatter mixture response curves than the regular-volatility fuels, and they reached peak knock-limited power at richer fuel-air ratios. This is illustrated by Fig. 1, which compares typical knock-limited mixture response curves for conventional-volatility gasoline and low-volatility fuels. Table 1 shows that a number of the low-volatility fuel blends gave the same or higher power outputs than were obtained with the Grade 100/130 aviation gasoline specified by the manufacturer for the R-1820 engine.

The fuels tested were rated in substantially the same order, lean and rich, by the Wright engine and a single-cylinder C.U.T. engine equipped with a cylinder identical to those used on the multicylinder engine, thus demonstrating the usefulness of the C.U.T. type of equipment for fuels quality evaluation.

The knock-limited performance data obtained show that whereas increasing the aromatic content of low-volatility fuel blends from 20 to 50% results in improved rich-mixture performance, it markedly decreases the lean-mixture cruise rating. The advantage of using the highest possible antiknock-quality aromatic concentrate is indicated, in that this reduces the antiknock requirement of the base stock necessary to make a given grade of low-volatility fuel.

Fuel consumption tests in the multicylinder Wright engine indicate that, although the minimum brake specific fuel consumption is essentially the same under

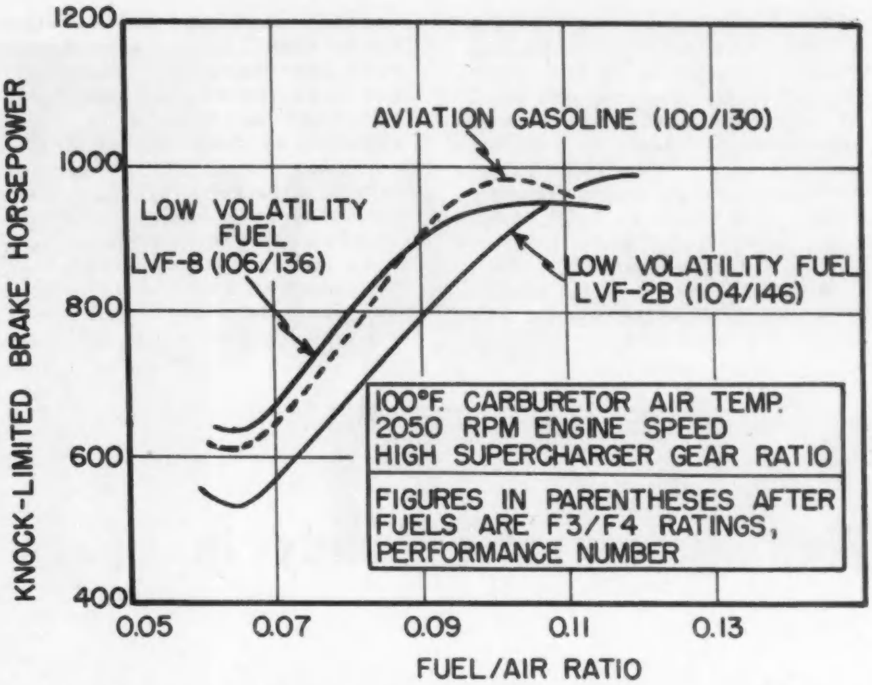



Fig. 1 - Knock-limited mixture response curves for low-volatility fuel and aviation gasoline in Wright R-1820 engine

Table 1 - Knock-Limited Performance of Fuels

| | | | R-1820 Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | F/A=0.065 | | F/A=0.09 | | F/A=0.10 | |
| Fuel | Aromatic, % volume | F-3/F-4 Rating | Cruise[a] | Take-off[b] | Cruise[a] | Take-off[b] | Cruise[a] | Take-off[b] |
| Low Volatility Fuels | | | | | | | | |
| LVF- | | | | | | | | |
| 1A | 0 | 80/85 | 90 | 97 | 92 | 95 | 83 | 87 |
| 6 | 0 | 110/120 | 111 | 104 | 118 | 121 | 118 | 124 |
| 3 | 0 | 124/149 | 141 | 133 | 151 | 144 | 156 | 138 |
| 2B | 20 | 104/146 | 107 | 110 | 122 | 129 | 125 | 134 |
| 4 | 20 | 110/152 | 129 | 126 | 150 | 140 | 165 | 147 |
| 5 | 20 | 117/170 | 138 | 132 | * | 151 | * | * |
| 14 | 20 | 100/117 | 93 | 85 | 114 | 117 | 114 | 117 |
| 8 | 20 | 106/136 | 123 | 121 | 132 | 141 | 129 | 145 |
| 10 | 50 | 100/157 | 90 | 111 | 152 | * | * | * |
| 9 | 50 | 104/165 | 95 | 109 | 160 | * | * | * |
| 11 | 100 | 108/>170 | 127 | 128 | * | * | * | * |
| Conventional Volatility Fuels | | | | | | | | |
| CVF- | | | | | | | | |
| 1 | 7 | 76/97 | 92 | - | 96 | 105 | 96 | 99 |
| 2 | 17 | 100/130 | 117 | 113 | 132 | 134 | 132 | 137 |
| 3 | 10 | 115/145 | 132 | 136 | 148 | 152 | 147 | 153 |

* No detonation encountered at full-throttle operation.

[a] High blower ratio

[b] Low blower ratio

certain conditions for both low-volatility and conventional-volatility fuels at the 19,000 Btu per lb net-heat-content level, it increases more rapidly for the low-volatility fuels as fuel heat content is decreased and as engine speed is increased. Consumption is as much as 1.5% higher for low-volatility fuels at 18,300 Btu per lb and 2050 rpm.

Multicylinder engine studies indicated that whereas under low-speed. low-temperature conditions, serious crankcase oil dilution (more than 12%) is experienced with low-volatility fuel, very low dilution (less than 1%) is obtained with conventional-volatility fuel. Under normal cruising conditions, however, only 4% dilution is obtained with low-volatility fuel, so that this problem should not be serious under ordinary circumstances.

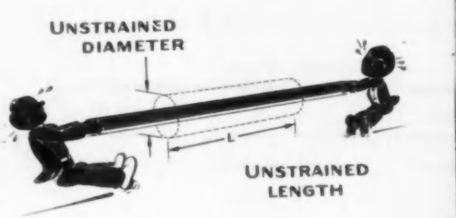
Although no specific investigation was made of the engine starting characteristics of low-volatility fuels, general observation indicated that this would be somewhat of a problem, particularly at low ambient temperatures. (Paper "Full-Scale Engine Performance Characteristics of Aviation Safety-Type Fuels," was presented at SAE Annual Meeting, Detroit, January 14, 1948. This paper is available in full from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

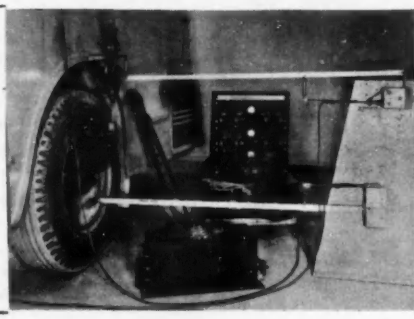
# Finding Dynamic Loads in Coach Structures

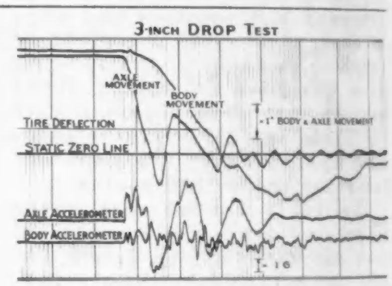
Based on paper by

W. E. RICE R. O. ELLERBY

GMC Truck & Coach Division






DETERMINING dynamic loads and stresses of motor coach structures with electrical strain gages helps predetermine structural performance. This technique tells where weight can be removed safely.

Instrumentation for this work must be reliable and stable. The resistance wire strain gage itself is simply a device which changes electrical resistance in proportion to applied strain. (Changing the wire's length and diameter, as in the cartoon above, varies its resistance in proportion to the strain applied.)

Used in conjunction with the gage are other pieces of electrical equipment, including a recording oscillograph which provides recorded measurements of items such as load, displacement, and strain.

One way in which this equipment is put to work is in a drop test to study damping and frequency characteristics of the suspension. At the same time, it permits evaluation of external acceleration - comparable to severe road shocks - at various structure and axle points. The test set-up is shown above.

Cantilever bars are used here together with a single reducing linkage to keep maximum deflection of the test bars within their elastic range. Long links are pinned to brackets, mounted on the wooden stand, and to short links connected to the body axle. The vehicle is raised by a chain fall connected to the axle bracket, linked to the chain hook with a small diameter bar. Cutting this bar after the coach wheel is hoisted for a 3-in. clearance between tire and bar produces the sudden drop.

Recording of the drop, above, traces movement of body and axle with respect to each other, in exact relationship to a common zero line. The lower two traces represent axle and body acceleration. Line of tire deflection indicates the point at which the tire hit the floor.

This record shows movement equivalent to severe road operating conditions. Actual vertical movement of the body and axle

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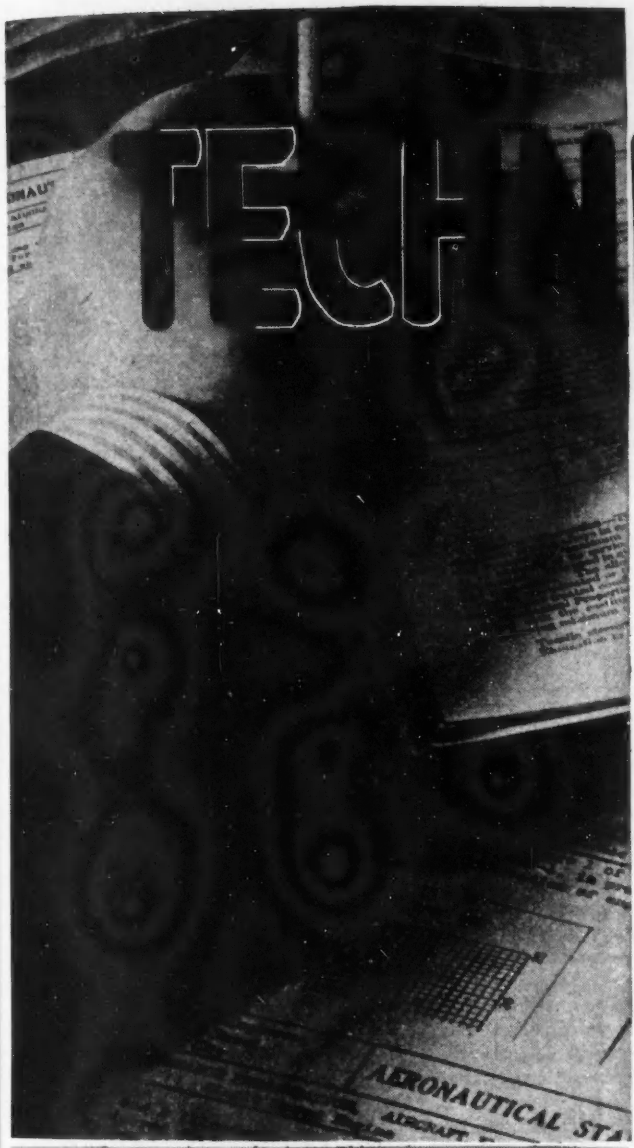
# TECHNICAL COMMITTEE PROGRESS






## Key, Moulding Standards Evolved by Body Group

SAE Body Engineering Committee's fertile program recently bore its first fruit in the form of a new standard on cylinder locks and keys and a recommended practice for mouldings and fasteners. Among other projects being cultivated by this group are a dimensional standard for windows and acoustical material specifications.

The key and lock standard includes a definition of the key sets, nomenclature and dimensions, and a lubrication and cleaning procedure.

According to the standard, the same key which operates the ignition switch lock should operate the vehicle door locks, and is designated the Primary Key Set. A separate key should be used for the luggage compartment lid and other locks on the car. But in no case should there be more than three different keys furnished. The new standard labels all keys, other than the primary set, the Secondary Key Set.

For quick identification and uniformity, the standard specifies a polygonal shape with flat faces and corners around the rim of the key bow of the primary set; periphery of the bow for the secondary key set may be a rounded shape - such as an oval or clovercleaf.

The Committee feels that prescribing key shape will help the driver quickly

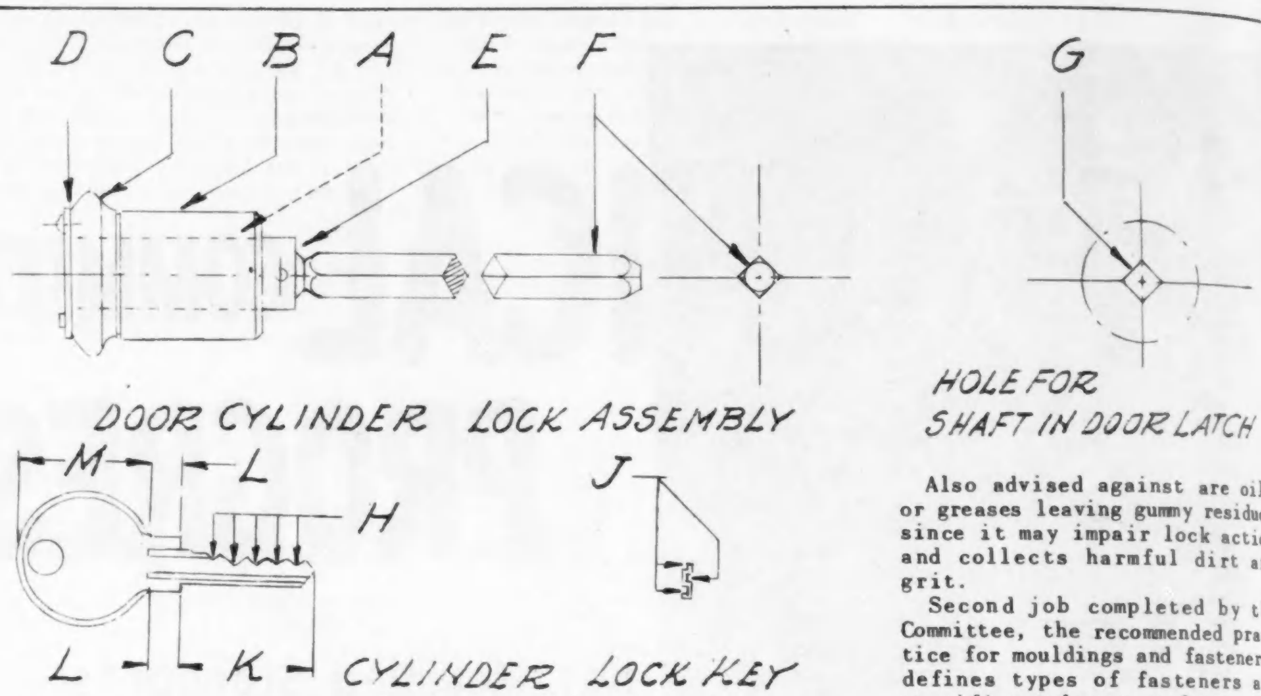



Fig. 1 - Cylinder lock and key nomenclature developed by the SAE Body Engineering Committee designates the following names for the above parts: A, plug; B, shell; C. brezel; D, key hole cover; E, joint; F, shaft; G, hole for shaft in latch; H, bitting; J. grooving; K, blade; L, shoulder; and M, bow

identify car keys, even in the dark. Such uniformity will be especially helpful to owners of more than one car, or to people who drive different cars. Although not all car manufacturers are furnishing keys conforming to the new standard, the Committee feels these recommendations will establish a pattern for future designs.

The lock nomenclature delineated in the standard that all key-operated locks - such as those for ignition switches, doors, compartments, lids, and gasoline filler caps - be designated "cylinder lock assemblies," with the name of the specific part preceding it - such as "door cylinder lock assembly."

Names for the principal lock and key parts given in the standard are shown in Fig. 1.

Before lubricating, it is advised that the cylinder lock be washed with alcohol or gasoline. This can be done by removing the assembly and submerging it, or by blowing the alcohol or gasoline through with air.

After cleaning, the lock should be lubricated with flake graphite - blown through the assembly with air or worked in with the key. Extremely coarse graphite with flakes average over 1/32 in. should not be used.

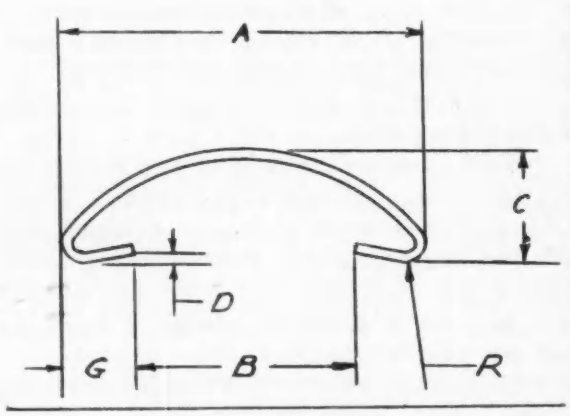



Fig. 2 - New SAE recommended practice for mouldings advises designers and drafts men how to specify the above dimensions. For example, a tolerance of $\pm$ 0.010 is recommended for dimension A in the case of straight mouldings. Tolerances on same with bent mouldings is said to be inadvisable. And with snap-on type fasteners, minimum dimension C should be 5/32 in. with 0.020 or lighter metal specified for oval shapes. Dimension C should be held to 1/8 in minimum with "flat top" shapes

Also advised against are oils or greases leaving gummy residue, since it may impair lock action and collects harmful dirt and grit.

Second job completed by the Committee, the recommended practice for mouldings and fasteners, defines types of fasteners and specifies tolerances for mouldings.

These are the four general type of fasteners listed:

1. Snap-On Type - Fastener is secured to panel first, then the moulding is snapped over the fastener.

2. Slide-In Type - Fastener is assembled into the moulding by sliding it into place before it is snapped to the panel.

3. Turn-In Fastener - Fastener is secured in moulding by turning fastener into moulding before being snapped to the panel.

4. Bolt and Nut Type - Moulding is secured to the panel with a nut and bolt.

Dimensional recommendations for mouldings are shown in Fig. 2. The Committee feels they should be particularly helpful to draftsmen.

Among the other Committee projects reported by Chairman E. C. DeSmet, Willys-Overland Motors Inc. are: a body and sheet metal nomenclature; specifications for fiber, cardboard, and paper; standards for window and door glass, window glass runways and channels, window regulators and inside door handles; and standard tests for acoustical materials. The SAE group has established liaison with the Automotive Welding Committee of the American Welding Society which hopes to standardize automotive welding procedures. P. C. Johnson, Willys-Overland Motors, Inc., has been appointed contact man, representing the SAE Body Engineering Committee on the AWS group.

## SAE Invited to Italian Auto Congress

An Automobile International Technical Congress, sponsored by the Associazione Tecnica dell' Automobile, will be held in Turin, Italy, during the period of the 31st Salon de l'Automobile of Turin, September 25-28, 1948. The program of the meeting will feature technical papers on agricultural motorization; carburetion and injection; body building; electrical equipment, fittings, brakes; and transport. SAE members are cordially invited to attend the Congress and to contribute papers or discussion. Members planning to attend are requested to so notify SAE Headquarters, Twenty-Nine West Thirty-Ninth Street, New York City - Attention: Meetings Division.

## Steels and Screw Threads Changed in '48 Handbook

Distribution of the 1948 SAE Handbook to the membership has just been completed. Outstanding additions made to it are the completely revised SAE standard steel specifications and a new comprehensive screw thread section. Other important first-time automotive standards and specifications are included in this 38th annual edition of the Handbook, that contains 60 pages more than last year's volume.

Some 72 new steel specifications, including 16 stainless steels, have been added, while 47 steels were removed from the steel standards listed in the 1948 Handbook. Other fresh material in the ferrous area published in the new edition includes general information on pearlitic malleable iron castings, steel hardenability bands, and carbon steel.

An expanded, easier-to-use screw threads section is featured in the 1948 Handbook for the first time. (It is also available in a separate publication in 8 1/2 x 11 in. format.) Brought up-to-date with American Standards developments and those relating to the Anglo-American Screw Thread Unification Proposals, the new material is arranged to eliminate necessity of referring to separate tables for different thread series.

The limiting dimensions of external and internal threads in all pitches have been tabulated in sequence for each diameter, requiring reference to only one table for each class of thread.

Among the other new standards SAE members will find in the 1948 Handbook are:

- Preignition Rating of Spark Plugs;
- Preventive Maintenance and Inspection Procedure;

(This provides a broad, flexible basis for periodic maintenance of all kinds of automotive vehicles.)

- Lighting Specifications for Back-Up Lamps, Parking Lamps, and Sealed Beam Unit Rings;
- Automotive Filler, Drain, and Pipe Plugs;
- Tractor Drawbar (Track Type).

Many existing standards have been brought up-to-date. For example, storage battery specifications have been streamlined and modified. And the addition of 20 new washer sizes is another of the more than 50 expansions and revisions made during the last year.

Members can get additional copies of the 1948 SAE Handbook from SAE Special Publications Department for $5.00 each; price to nonmembers is $10.00.

## Tool Steel Classifications Tackled by SAE Committee

POSSIBILITY of identifying and classifying tool steels for the metallurgically-untrained in industry - such as tool makers, tool room foremen, and commercial heat treaters - is being explored by the SAE Iron & Steel Technical Committee's Non-Productive Steels Division.

A simple listing of this kind, the Committee members feel, would minimize costs, inconvenience, and confusion - from manufacture of the steel to heat-treatment of the finished tool. In preliminary discussions, it was pointed out that such classification holds a two-fold advantage. First, it would provide users with more knowledge of advantages and limitations of these steels. Second, it would promote more accurate and skillful heat treatment.

Committee member A. O. Mason, Ternstedt-Fisher Division, GMC, visualizes a tool steel breakdown into these six general classes:

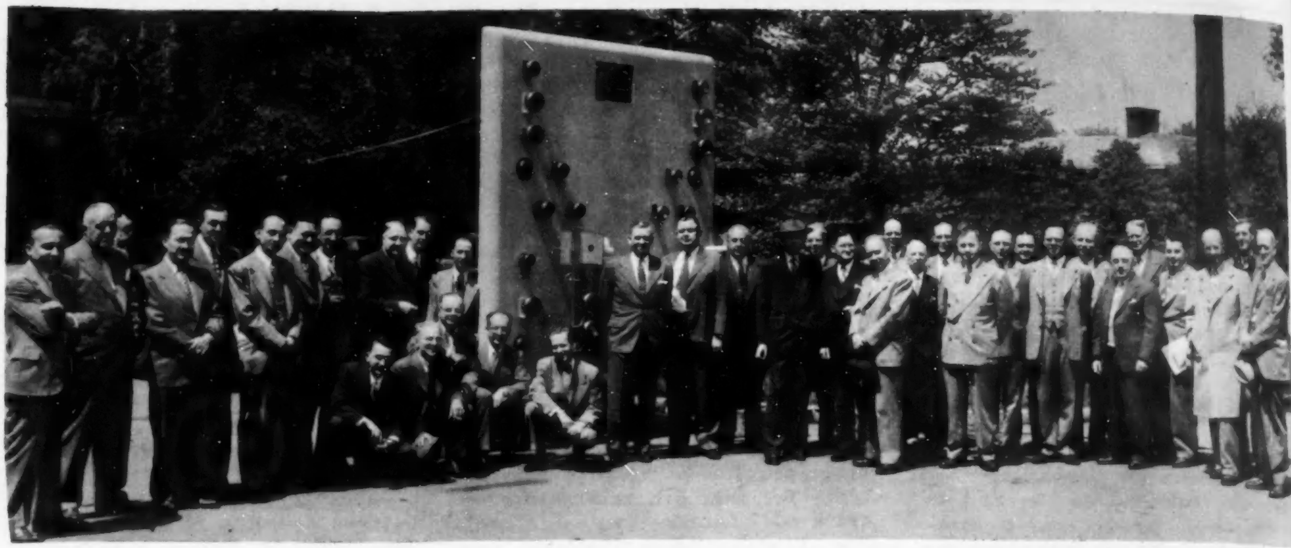
1. Water Hardening Tool Steels,
2. Oil Hardening Tool Steels,
3. Air Hardening Tool Steels,
4. Tool Steels for Severe Cold Impact Applications,
5. Hot Work Tool Steels, and
6. High Speed Tool Steels.

## Committee Personnel

Appointments to technical committees recently confirmed by the SAE Technical Board include:

- R. B. Hooper, Chrysler Corp., will serve as SAE representative on ASTM Committee E-3 on Chemical Analysis of Metals.
- H. A. Werme, New England Screw Co., now is member-at-large on SAE-sponsored ASA Sectional Committee B18 - Bolts, Nuts, Rivets, Screws, and Similar Fastenings.
- C. O. Durbin, Chrysler Corp., succeeds J. L. McCloud, Ford Motor Co., as SAE representative on ASTM Committee A-5 on Corrosion of Iron and Steel.
- L. M. DeTurk, ACF-Brill Motors Co., has been named a member of the Highway Research Board's Committee on the Economics of Motor Vehicle Size and Weight.
- V. C. Speece, White Motor Co., succeeds A. H. d'Arcambal, Pratt & Whitney, as an SAE representative on ASA Sectional Committee B-5 on Standards for Small Tools and Machine Tool Elements.
- T. A. Weiss, Jr., Republic Aviation Corp., recently accepted the chairmanship of the SAE Aircraft Electrical Equipment Committee.

E. S. MacPherson, Executive Engineer of the Ford Motor Co., has been appointed as an SAE representative on CRC Governing Board to replace W. S. James



Members and guests of the SAE Lighting Committee participated in demonstration of flash-type directional signals for trucks and warning signals for school buses at the General Electric Nela Park Laboratories

# Establish Signal Light Needs For Trucks and School Buses

TENTATIVE agreement on design of truck directional signals (of the flashing type now offered as regular equipment for passenger cars) was reached at the last meeting of the SAE Lighting Committee. School bus signals also were discussed. Demonstrations at General Electric's Nela Park Laboratories immediately preceding the meeting helped clarify points in both areas.

Among the optical requirements tentatively deemed necessary for experimental design of directional signals for trucks were the following:

1. Signal lamps should provide plain illuminated areas (no arrows or wording required).

2. Minimum exposed luminous area should be 12 sq. in.

3. This type of truck signal should be used on vehicles 80 in. or wider, on vehicles requiring side-marker lights, or where hand signals cannot be seen.

4. Signal lamps should show red to the rear, amber to the front - with colors conforming to the SAE color specification.

5. The red signal lamps should have 35 cp minimum at the H-V point. (It was agreed not to specify a maximum.) It also was agreed that within the vertical angles 5 deg up and down and the horizontal angles 10 deg right and left, the minimum candlepower should be 25. A minimum of 10 cp was felt necessary within vertical angles 10 deg up and down and 20 deg right and left. Amber signal lamps are to provide four times the candlepower values agreed upon for red.

6. Rate of flashing should be between 60 and 120 flashes per min.

Turning signal demonstrations at the General Electric Automotive Lighting Laboratory, organized by a subcommittee under the chairmanship of P. J. Kent, Chrysler Corp., aided the Committee in reaching some of these decisions.

For example, most of the 36 engineers witnessing the demonstrations felt that wording or arrows on both red and amber lamps were hardly visible at 100 ft in daylight, and even legibility at night at this distance was questionable. At 300 to 500 ft, arrows or words blotted out what could have been illuminated area.

Different shaped and sized openings also were tried, with almost unanimous preference voiced for a 4-in. diameter circular opening. Other daylight tests showed that red signals are more easily seen than amber ones, unless the amber signal has considerably more beam candlepower.

## SCHOOL BUS SAFETY

The problem of warning lights for school buses stems from the fact that an increasing number of states require all traffic, in both directions, to stop when a school bus stops to discharge or pick up pupils. Although painting school buses chrome yellow facilitates daylight identification, signal lamps must supplement this

and must also serve for night-time identification.

School authorities in some states already are moving in the direction of requiring flashing type signals on school buses. Work of the Committee is aimed at promoting uniformity of these requirements among the states.

Current thinking among the conferees has it that the school bus warning signal specification should conform to requirements set up for the truck directional signal, except that both the front and rear lamps should flash alternately, each to flash 60 to 100 times per min.

The Nela Park demonstrations impressed the group with the effectiveness of flashing lamps on each side of the vehicle as a school bus signal. It was generally felt that this would be an easily understood signal, definitely distinguishable from the directional signal where only one light is flashed.

Another item up for Committee consideration is a proposal to revise optical values for Class A reflex Reflectors now specified in a SAE Recommended Practice. This matter was tabled pending further standardization of a method for determining these values.

## Tech Board To Move Up Handbook Publication Date

A new plan is being put into motion to speed up publication of the SAE Handbook, beginning with the 1949 edition.

Waiting for reports and material in process of approval for the Handbook at and after publication deadline has been a chief source of delay. Under the new arrangement, last material to be accepted for publication will be approved by the SAE Technical Board at its meeting during the SAE Annual Meeting. Such reports must be in the Board's hands at least two weeks before the meeting.

This arrangement, the Technical Board feels, will give its standards-making groups a definite deadline to work to in preparing material planned for the succeeding year's Handbook.

## SAE Group Named To Help Ordnance

SAE Ordnance Technical Committee has been established to assist the Army on postwar ordnance problems where the Army feels the need for cooperative work among automotive engineers.

An outgrowth of an SAE Technical Board study undertaken shortly after World War II ended, personnel of the new standing committee is: Chairman, J. M. Crawford, General Motors Corp.; B. B. Bachman, Autocar Co.; L. R. Buckendale, Timken-Detroit Axle Co.; C. E. Frudden, Allis-Chalmers Mfg. Co.; E. S. MacPherson, Ford Motor Co.; and J. C. Zeder, Chrysler Corp.

The new committee provides a permanent agency for continuation in peacetime of the type of cooperation with Ordnance which, during World War II, won for SAE the first Ordnance Distinguished Service Award.

## Technigrams. . .

COLORED WASHERS: In developing a standard for washers, the SAE Engine and Propeller Utility Parts Committee is considering the use of dyes as a means of identification. Colors such as green, brown, and black could be used, said some of the Committee members, to distinguish between constant quality engine and propeller washers being developed by the Committee and regular AN 960 washers. Notching or circumferentially grooving washers for identification was considered impractical and too expensive.

FASTENER NOMENCLATURE: The big job of developing a glossary of terms for all kinds of mechanical fasteners, to give mechanical industries a much needed "dictionary" on these parts names, has been undertaken by ASA Sectional Committee B18 on the Standardization of Bolt, Nut, and Rivet Proportions. In addition to word definitions, this treatise will include sketches and dimensional ranges of the various types of mechanical fasteners. The group is sponsored by SAE and ASME.

WELDING DRAFTING: A new section planned for the SAE Aeronautical Drafting Manual will show ways of indicating on drawings all phases of aeronautical welding - such as spot, seam, arc, and gas welding.

PLANE AIR CONDITIONING: First of a four-part series entitled "Airplane Air Conditioning Engineering Data, was just published by the SAE Aircraft Air Conditioning Equipment Committee. This first publication, Aeronautical Information Report No. 22, Properties of the Atmosphere, contains NACA standard atmosphere tables and data, summer atmosphere tables, and charts on moisture content of the atmosphere at different altitudes. Other reports for this series now in process are Fluid Dynamics, Heat Transfer, and Thermo Dynamics.

STOPPING CORROSION: The SAE Iron & Steel Technical Committee recently undertook a new program to study ways of preventing corrosion of iron and steel. The job is being broken down into these six groups: (1) Electroplating, (2) Hot Dip and Metallic Coatings, (3) Organic Coatings (paints, enamels, lacquers), (4) Temporary Coatings (oils, plastic dips, chemicals), (5) Chemical Surface Coatings, and (6) Ceramic Coatings. Work on organic, chemical, and ceramic coatings will be carried on jointly with the SAE Non-Ferrous Metals Committee for protection of both ferrous and nonferrous metals.

# About

Two former Air Force Generals, Major General Robert B. Williams, center, and BRIGADIER GENERAL HAROLD R. HARRIS, left, now executives of American Overseas Airlines, recently received high British military decorations from Sir Francis Evans, right, British Consul General. The two AOA officials were parts of a group of 36 American citizens who received British military and civil awards during presentation ceremonies held aboard R.M.S. Brittanic

ROGER MAHEY is automotive editor of the Los Angeles News. Leaving the SAE headquarters staff where he was assistant manager, Membership and Sections Division, to make his home on the Pacific Coast, Mahey was immediately pressed into service as an active member by Southern California Section. Coincident with taking up his duties on the LA News, he has been named publicity chairman by the Section.

DR. JAMES (JIMMY) H. DOOLITTLE was recently named a member of the National Advisory Committee for Aeronautics by President Truman.

Prior to becoming lubrication sales engineer with the Sinclair Refining Co. in New York City., GEORGE E. KELLIS was an automotive engineer with the Richfield Oil Corp. of New York, same city.

Previously a manufacturer of farm implements in a company under his own name, OLIVER W. INSKEEP is now consulting mechanical engineer for Thompson Sage, Inc., Stockton, Calif.

No longer district manager of Thompson Products, Inc., Cleveland, Ohio, HOWARD T. EATON, JR., has become advertising solicitor of the Curtis Publishing Co., same city.

Now president and manager of Hilligoss & Son, Inc., Shelbyville, Ind., DONALD G. HILLIGOSS had been quality engineer, Thompson Products, Inc., Cleveland, Ohio.

JOSEPH R. BENGOECHEA, formerly natural gas engineer with the Federal Power Commission, Washington, D. C., is now mechanical engineer for the Army Air Materiel Command, Wright Patterson Field, Dayton, Ohio.

JAMES E. WASEM, JR., recently accepted a position with the Research & Development Department of the Socony-Vacuum Laboratories at Paulsboro, N. J., as a mechanical engineer in research and development. He had been a mechanical engineering instructor and graduate student with the University of Delaware, Newark, Del.

THOMAS N. KELLY, newly appointed assistant vice-chairman of the Aeronautics Activity for the Detroit Section has accepted a position as chief engineer and assistant general manager of the Smith-Morris Co. in Ferndale, Mich. This company manufactures aircraft exhaust systems. Kelly was previously project engineer in charge of ram-jet powerplants for Continental Aviation & Engineering Corp.

Recently joining the National Advisory Committee for Aeronautics, Aircraft Engine Research Laboratory as a research engineer, JOSEPH FRANK SLOMSKI had been a test engineer for the Laboratory Equipment Co. in Mooresville, Ind.

HOWARD JARMY, now development engineer with Boeing Aircraft Co. in Seattle, Wash., had been research assistant on noise reduction and vibration for Illinois Institute of Technology, Chicago.

GEORGE W. MASON has been elected chairman of the board of the Nash-Kelvinator Corp. Since the merger of Nash Motors Co. with Kelvinator Corp. in 1937, Mason has supervised the operating management of the corporation. Prior to the merger he had been president and chairman of the board of Kelvinator.

Mason will continue to serve as president of Nash-Kelvinator Corp.

Now district manager of West Texas and New Mexico for Buda Engine & Equipment Co., a subsidiary of the Buda Co., Harvey, Ill., JOHN WALLACE HUGHES had been service manager for this company.

# SAE Members

Heretofore field service manager for Standard Brands, Inc. in Philadelphia, Pa., ALFRED E. TOWNSEND recently became divisional supervisor for the Atlantis Sales Corp., same city.

CARL DOLAN is executive director of the Joint Congressional Air Policy Board in Washington, D.C.

The appointment of HAROLD F. HAMMOND as manager of the Transportation & Communication Department has been announced by the U. S. Chamber of Commerce. He was formerly affiliated with the American Transit Association and has been assistant manager of USCC's Transportation & Communication Department since April, 1947.

HARRY R. RICARDO, chairman and technical director of Ricardo & Co. of England, writing in the May-June issue of the Journal of Associazione Tecnica dell'Automobile of Italy, concludes that "the fuel outlook is becoming painfully clear and the engine which will survive will be that which can best digest the much more difficult fuels which will be our portion." The distinguished scientist points out that in Great Britain the rapidly extending use of the gas turbine for aircraft constitutes a serious drain on dwindling supplies of middle distillates, more especially the lighter diesel fuels and kerosenes. "It seems," he says, "that in the near future we shall have to cope with fuels of low volatility, poor ignition quality (low cetane value) with high ash content, and which, on account of their high viscosity, will be much more difficult to filter efficiently."

FREDERICK C. BRANDT has opened an engineering service of professional engineers in North Hollywood, Calif. It is going to serve the San Fernando Valley and Los Angeles in product research, tool and machine design in a consulting and engineering capacity. One of his partners is HUGO FRIES, formerly of Detroit.

JOSEPH E. PADGETT was recently elected vice-president and a member of the board of directors of Solar Aircraft Co. where he has been director of manufacturing for about a year. An SAE Past Vice-President, Padgett is now in the midst of an expanding program in the manufacture of high temperature parts for jet engines.

WALTER W BISHOP, former industrial relations consultant in New York and wartime personnel director with Wright Aeronautical Corp., Paterson, N. J., has been appointed to take charge of the Piasecki Helicopter Corp. industrial relations activities.

LEROY R. GRUMMAN, chairman of the board of Grumman Aircraft Engineering Corp., has been awarded the 1948 Daniel Guggenheim Medal for "outstanding achievement in successfully advancing aircraft design both for Naval and peacetime use."

KARL K. PROBST has resigned as chief engineer of Reo Motors, Inc. Lansing, Mich., and plans to engage in development and consulting work next autumn. Probst has been with Reo for over three years and layed out the post-war program for vehicles that are now all in production or on test.

GEORGE W. DAVIES has been appointed general sales manager of the Sealed Power Corp. Having been in the employ of this company for the past 14 years, he was formerly sales manager in charge of the original Equipment Piston Ring Division.

CLARENCE E. DAVIES, national secretary of the American Society of Mechanical Engineers, has been given the honorary degree of Doctor of Engineering by Clarkson College of Technology, Potsdam, N. Y. Davies has been associated with the ASME since 1920, becoming its national secretary in 1934.

PAUL C. JOHNSON has been named executive vice-president of Sealed Power Corp., Muskegon, Mich. Johnson has been vice-president in charge of sales since 1941 and has been with Sealed Power since 1929. In his new post he succeeds NEIL A. MOORE, who resigned as vice-president and general manager after serving Sealed Power for 24 years.

BRIGADIER G. MacLEOD ROSS, of the British Army, recently received the Legion of Merit, Degree of Officer, by the President of the United States for "exceptionally meritorious service to this government."

EDWARD C. DITZEN, formerly production engineer for United Engineering Co., San Francisco, has been promoted to chief engineer of that firm. He assumes overall responsibility for the engineering of the company's diversified line of products. Ditzen was previously a design engineer for Sterling Engine Co., Buffalo, N. Y.

CAPT. EDDIE RICKENBACKER, president of Eastern Airlines, will address the opening session of the Illinois State Chamber of Commerce Aviation Conference at Peoria, Ill., Aug. 5-6. Objective of this conference, which the State Chamber intends to make an annual institution in Illinois, will be to marshal opinion on the future of aviation, to discuss problems and policies, and to clarify plans for the future of aviation in Illinois and the nation.

MAURICE BENTON, previously connected with Jorgensen & Schreffler, Miami, Fla., has accepted a position as mechanical engineer with Maurice H. Connell & Associates, same city. In his new post he designs air conditioning and heating systems for commercial and residential buildings.

Now affiliated with the Western Ford Motor Coach Sales Co., Inc. in Seattle, Wash., EVAN S. PRICHARD had been with Tricoach Co., Inc., same city.

Previously assistant project engineer with Wright Aeronautical Corp. in Wood-Ridge, N. J., HERBERT H. HOWELL has now become associate engineer for the Applied Physics Laboratory of the Johns Hopkins University in Silver Spring, Md.

Recently graduated from the Case Institute of Technology in Cleveland, R. E. LUECHT has become a project with Newport Industries, Inc. in Pensacola, Fla.

GORDON K. STEBBINS is now general manager with the Charles A. Lampard Co. in Stratford, Conn. His duties include the management of business and technical affairs of the company.

In recognition of his company's efforts to promote the interests of humanitarianism as applied to animals, DAVID A. WALLACE, president of the Chrysler Division, was recently given a plaque by the American Humane Society at a dinner in Detroit.

Demonstrating the Varimatic, a small-scale model propeller which he invented, is JOHN WAUGH, Koppers Co., Inc., Baltimore. He shows the two extreme positions which the propeller assumes. The prop he is holding is in high pitch position and the prop mounted on the gas engine is in low

The Book "Supercharging the Internal Combustion Engine," by E. T. VINCENT, Consulting Engineer, Continental Aviation and Engineering Corp., just was published by the McGraw-Hill Book Co., Inc. Concerned with automotive, diesel, and aircraft engines, this treatise spells out supercharging theory and gives design analysis techniques. It also makes a practical evaluation of current types of superchargers and describes their principle of operation.

CONTINUED ON PAGE 90

# OBITUARIES

## DR. GEORGÉ W. LEWIS

One of the world's leading authorities in aeronautics, and the man chiefly responsible for maintaining the National Advisory Committee for Aeronautics a strong research establishment through the years, Dr. George W. Lewis died July 12 at his summer home at Lake Winota, Pa.

He served as an SAE vice-president in 1931 and again in 1941, and was an SAE councillor for the 1933-34 term. He was chairman for many years of the long-active SAE Research Committee, and served several terms as chairman of the SAE Publication Committee.

A graduate of Cornell in 1908, he instructed in engineering and obtained his master's degree there two years later. He was professor of mechanical engineering at Swarthmore College from 1910 to 1917.

Two years later he became executive officer of the World War I-born NACA when it had a small wind tunnel and 16 employees. Last August, when he retired as director of research to become NACA top consultant, the research organization represented a government investment of nearly $100 million, and had more than 6000 employees in three laboratories which were equipped with 40 wind tunnels, several of which are the world's most advanced in design.

He is personally credited with development of the variable-density wind tunnels, refrigerated free flight wind tunnels, and the supersonic speed tunnels. His early engineering work was on the Roots supercharger for aircraft engines.

A former president of the Institute of the Aeronautical Sciences, a member of the National Academy of Sciences, he was also a member of many technical and scientific organizations, and was the 1936 Guggenheim Medalist. He had been honored by several foreign countries and universities.

## LAWRENCE B. JACKSON

One of the nation's distinguished authorities on diesel engine design, Lawrence B. Jackson, who retired a year ago as director of engineering of the Diesel Division of American Locomotive Co., died on July 4 at the age of 63 in his home in Schenectady, N.Y.

A graduate of Stevens Institute of Technology, Jackson was responsible for equipping the first diesel engine tankers for the Texas Co. Then for 18 years he was in charge of the development of the Fairbanks, Morse high speed diesels for submarines and other installations. He was manager of engineering of the Beloit Co.

For the five years preceding his retirement he directed the diesel engineering at American Locomotive Co., and was responsible for the powerplants of many modern streamlined trains.

## A. K. BRUMBAUGH

A. K. Brumbaugh died in his home at Palo Alto, Calif. on June 29. He was in his 64th year.

Few members had a wider acquaintance throughout the Society than "Brummy," who was the warm heart of innumerable SAE gatherings and events. He played many roles in SAE during his 32 years of membership. He twice served the Society as a Vice-President - for Production in 1931 and for Truck & Bus in 1934. He was once chairman of the Truck Division of the SAE Standards Committee and served also in the Storage Battery Division. In 1932 he was chairman of the Sections Committee. He was chairman of the old Pennsylvania (now Philadelphia Section) in 1919-1920. He had been nominated for the 1927-1928 chairmanship when he moved from the engineering duties which had occupied him at Autocar Co. since 1915 to join White Motor Co. in Cleveland as commercial engineer.

The later years of his life were spent on the Pacific Coast where, after a period with Timken-Detroit Axle Co., he became interested in design and manufacture of specialty, heavy-duty trucks as vice-president of engineering of the Knuckey Truck Co. at San Francisco.

He was a football star at Lehigh University, where he graduated in 1909 in electrical engineering. Between graduation and his joining Autocar he worked on development of electric vehicles at Westinghouse and was in charge of transportation problems for Consolidated Gas & Electric Co. in Baltimore.

He is survived by a wife, one son and one daughter.

## E. D. JOHNSON

While traveling from St Louis to Allentown, Pa. on June 7, E.D. Johnson was critically injured in a train wreck, and passed away as a result of those injuries on June 19.

At the Columbus, Ohio, depot the sleeping car in which he was riding left the tracks and sideswiped the engine of another train waiting to pull into the station. Firemen worked for more than an hour to free him from the wreckage.

Johnson was 45 years old and at the time of his death was in charge of automotive road testing, as well as application engineering of all passenger car and truck braking equipment for the Wagner Electric Corp., St. Louis, Mo. He had been with this company since 1926.

# SAE National

# TRACTOR and DIESEL ENGINE MEETING

**Hotel Schroeder, Milwaukee, Wisconsin,**

**Sept 7-9, 1948**

TUESDAY

9:30 A.M.

A. W. POPE, Jr., Chairman

Studying Diesel Combustion with the Cathode Ray Indicator
-W. C. HADLEY, J. R. HUDNALL and A. E. TRAVER, Socony-Vacuum Oil Co.

A Railroad Diesel Engine Improvement Based on Study of Combustion Phenomena and Diesel Fuel Properties.
-H. W. BARTH, F. A. ROBBINS and H. C. LAFFERTY, Electro-Motive Division, General Motors Corp.

(Sponsored by Diesel Engine Activity)

12:00 Noon Special Luncheon

FIFTH FLOOR - BANQUET ROOM

For time saving and convenience, the Hotel Schroeder has arranged to serve special luncheons, Tuesday, Wednesday, and Thursday, September 7-9, in the Banquet Room located on the fifth floor. This will permit those attending afternoon sessions to be there promptly at 1:30 P.M.

Tickets will be on sale - fifth floor foyer. PRICE $1.75 EACH

1:30 P.M.

W. F. JOACHIM, Chairman

Fuels for Automotive and Railroad Diesel Engines
-J. J. BROEZE and C. STILLEBROER, "Delft" Laboratory, Royal Dutch Shell

Influence of Fuel Composition on Deposit Formation in High Speed Diesel Engines
-H. M. GADEBUSCH, Detroit Diesel Engine Division, General Motors Corp.

(Sponsored by Diesel Engine Activity)

8:00 P.M.

H. L. RITTENHOUSE, Chairman

The Relation of Rated Capacity to Pay Yards, in Earthmoving Equipment
-D. K. HEIPLE, R. G. LeTourneau, Inc.

(Sponsored by Construction Industrial Machinery Technical Committee)

WEDNESDAY

9:30 A.M.

L. D. THOMPSON, Chairman

Cylinder and Piston Ring Wear in Diesel Engines
-J. W. PENNINGTON, Caterpillar Tractor Co.

(Sponsored by Diesel Engine Activity)

1:30 P.M.

W. H. WORTHINGTON, Chairman

Application of Hydraulic Transmissions
-R. M. SCHAEFER, Allison Division, General Motors Corp.

Planetary Transmissions for Agricultural and Industrial Tractors
-H. W. SIMPSON, Consulting Engineer

(Sponsored by Tractor and Farm Machinery Activity)

THURSDAY

9:30 A.M.

C. E. FRUDDEN, Chairman

Discussion of Power Losses in Tractor Engines
-H. T. MUELLER and K. L. PFUNDSTEIN, Ethyl Corp.

More Effective Utilization of High Octane Fuels
-A. T. COLWELL, Thompson Products, Inc.

(Sponsored by Tractor and Farm Machinery Activity)

1:30 P.M.

C. A. HUBERT, Chairman

Tractor Tire Testing Machine
-J. W. SHIELDS, United States Rubber Co.

Design and Power Requirements of Rotary Tillers
-L. E. LURA, Lavers Engineering Co.

(Sponsored by Tractor and Farm Machinery Activity)

DINNER

7:00 P.M. Ballroom

G. W. CURTIS and H. F. BRYAN, Co-Chairmen

F. G. SHOEMAKER, Toastmaster

R. J. S. PIGOTT, SAE President

FUTURE POWERPLANTS FOR TRACTORS AND ROAD MACHINERY

C. G. A. ROSEN, Director of Research, Caterpillar Tractor Co.

FRIDAY September 10

10:00 A.M. Ozaukee Country Club

SAE Milwaukee Section

Annual Golf Tournament

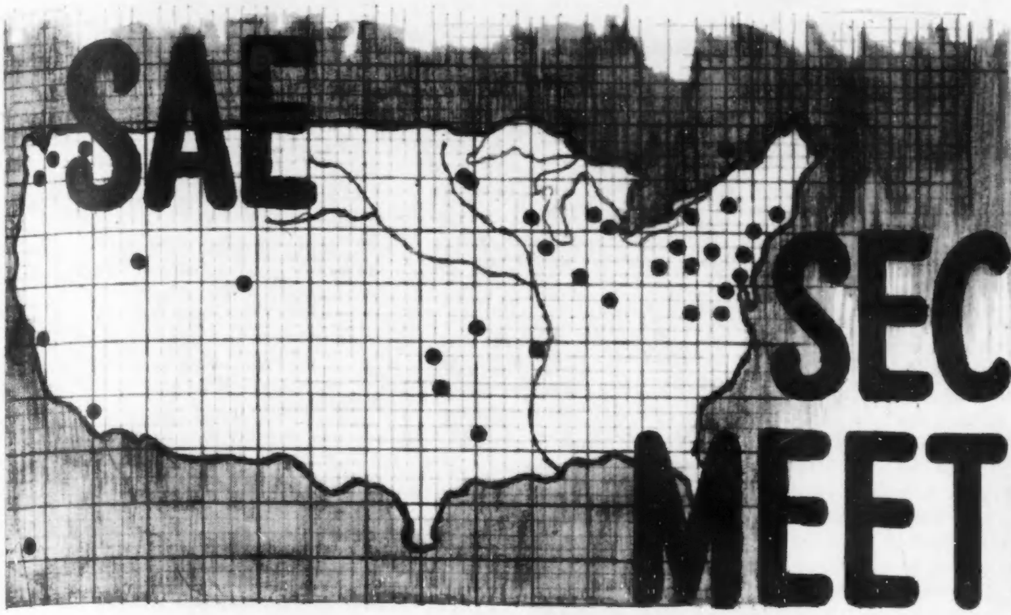
SAE Members and Guests attending the meeting are cordially invited to stay over and attend.

6:30 Dinner

Awarding of prizes 8:00 P.M.

Igor Kamlukin - Entertainment Chairman Allis ChalmersCo., Tractor Division.

# SAE SECTION MEETINGS



Discussing trends in passenger car styling, W. Everett Miller commented that while European designs accent sport and American designs aim at utility, European designs are setting American car styles.

CANADIAN Section resumed its annual golf tournament, suspended since 1942 because of the war, at the Kitchener Golf and Country Club with the V. F. Goodrich and Dominion Rubber Companies acting as hosts.

Past Chairman Jim Armer won the Section's Tiny Huston Memorial Trophy, provided by Past-Chairman Robert Combs for competition among the Section's Past Chairmen. The 168 members and guests enjoyed golf and dinner in spite of thunder showers.

Canadian Section's Governing Board has decided to proceed with publication of a roster of Canadian members.

BRITISH COLUMBIA Group's Past Chairman Phil Schrodt outlined the history of the Society at the June 11 election meeting. The Group is proud of its membership standing: 82 members and 20 applicants.

At the April meeting, WESTERN MICHIGAN Section heard Lt. Col. J. B. Fornasero discuss wartime and peace time flying. Speaker at the May Meeting was Albert H. Deimel, who talked on torque converters.

Three Student Branches continued activities until almost the end of the semester. University of Colorado Branch heard Ray Kelly compare the reciprocating engine with various jet engines. He listed a number of reasons why turbojets and turboprops will not be in general use for some time: Their development has not reached airline standards of safety and reliability.

Their enormous fuel consumption would require that aircraft be dispatched and landed exactly as scheduled. Turboprop controls are especially complex. These are some of the problems that give opportunities for the new crop of engineers to make real contributions to technical advancement, he said.

Enrollees at the Northrup Aeronautical Institute Branch took a trip to McCulloch Motors at Los Angeles to inspect production lines turning out engines for power saws and lawn mowers. At the May 26 business meeting, the treasurer reported that funds exceed $100.

Members of the General Motors Institute Student Branch have toured General Motors Proving Grounds at Milford, Michigan, visiting all the shops and laboratories as well as touring the road system.

Finding the best product to do the job was the theme at a number of recent Section meetings, one on fuels for light planes and others on trucks, gear lubricants, and passenger cars.

CONTINUED ON PAGE 85

New officers of the Student Branch at Northrop Aeronautical Institute receive congratulations from Institute Director James L. McKinley. With Faculty Advisor M.V. Christman, left, are H.O. Spaulding, Secretary; T. R. Gensel, Treasurer; W.G. Smith, Vice-Chairman; R. G. Elliot, Chairman; and McKinley. NAI has the largest Student Branch

# SAE Section Chairmen

ARMSTRONG

. . . . of Canadian

Ed Armstrong started on his way to becoming Chief Engineer of General Motors of Canada by joining the company's engineering department at Oshawa just after he was graduated from the University of Toronto in 1922. In 1928, he became Resident Engineer at the Walkerville plant, which was then producing axles, trucks, and buses. Three years later, he returned to the Oshawa plant, and in 1938 was appointed Chief Chassis Engineer.

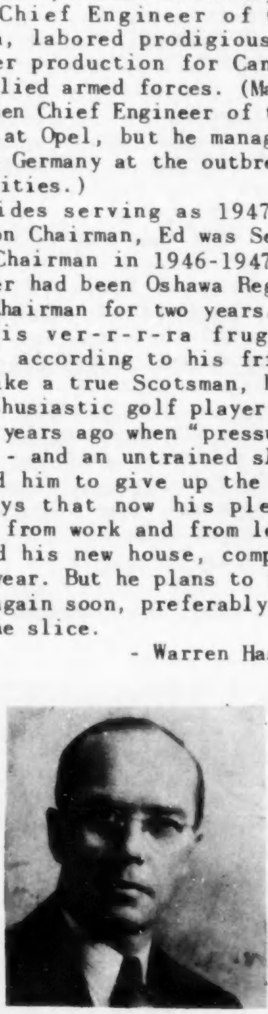
His appointment as Assistant Chief Engineer came in 1946, and it was two years later that he was named Chief Engineer.

During World War II, Ed, working closely with Albert A. Maynard, then Chief Engineer of GM of Canada, labored prodigiously to further production for Canadian and Allied armed forces. (Maynard had been Chief Engineer of the GM plant at Opel, but he managed to escape Germany at the outbreak of hostilities.)

Besides serving as 1947-1948 Section Chairman, Ed was Section Vice Chairman in 1946-1947, and earlier had been Oshawa Regional Vice Chairman for two years.

Ed is ver-r-r-ra frugal of words, according to his friends. And like a true Scotsman, he was an enthusiastic golf player until a few years ago when "pressure of work" - and an untrained slice - caused him to give up the game. He says that now his pleasure comes from work and from loafing around his new house, completed last year. But he plans to resume golf again soon, preferably without the slice.

- Warren Hastings



ZIPP

. . . . of Wichita

Harold W. Zipp, now Chief Engineer for the Wichita Division of Boeing Airplane Co., started designing his first airplane at the age of 15. He and his cousin built the plane in Lincoln, Neb., during their summer vacation in 1921.

That same summer, to get experience in the shops and to improve his airplane, Zipp went to work without pay for the Harding-Zook-Bahl Co., which manufactured a 3-cyl engine called the "Lark".

With a degree in mechanical engineering as his goal, Zipp enrolled at the University of Nebraska. However, in the spring of 1928, before he was graduated, a newspaper advertisement brought him to Wichita to become the entire engineering department of the Laird Airplane Co. Leaving Laird the following year, Zipp worked for Knoll Airplane Co. of Wichita for a short time before he decided to return to college.

He completed requirements for his mechanical engineering degree in 1930, and took up four different jobs in rapid succession. The first, with Arrow Aircraft Corp. in Lincoln, he held part time while completing college. After graduation, he left Arrow and went to work for the Winkler-Koch Engineering Co., the Great Lakes Pipe Line Co., and then Phillips Petroleum Co. In 1931, he left Phillips to become a draftsman for Stearman Aircraft Corp., now known as the Wichita Division of Boeing Airplane Co.

During the following six years, he was successively Project Engineer, Chief Draftsman, and Assistant Chief Engineer; and in 1937 he became Chief Engineer.

The engineering on the armed services' popular trainer, the Boeing Kaydet - 10,346 of which were built for the United States Army and Navy and Allied forces during World War II - was accomplished under Zipp's supervision. Also, responsibility for Boeing-Wichita engineering on the 1644 B-29's turned out by the Wichita Division fell to him. His efforts since the war have been toward the development of peacetime aircraft.

Zipp and his wife, Pauline, have a 10-year old son, Stephen. Besides work and family, Zipp is interested in IAS, Kiwanis, and Pi Kappa Alpha activities, and in flying, photography, and his home workshop.

- W. A. Day

MORRISON

. . . . of Cincinnati

Ralph E. Morrison began his association with the automotive industry back in 1914, as an accountant, not as an engineer. He was the Certified Public Accountant hired to consolidate the old United States Motor Truck Co. of Cincinnati and the Stewart Truck Co. of Covington, Ky.

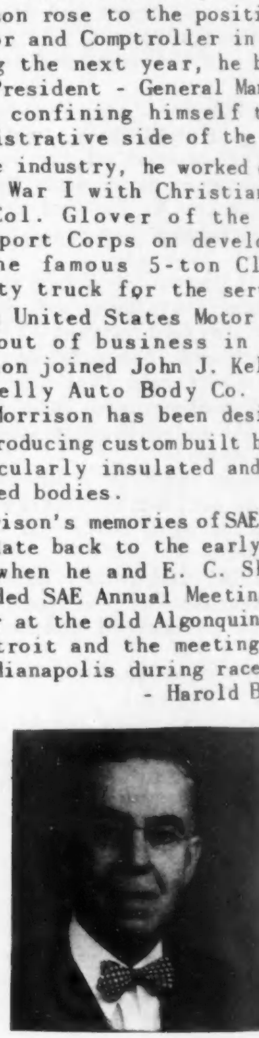
In the new company, the United States Motor Truck Co., Inc., Mr. Morrison rose to the position of Auditor and Comptroller in 1918. During the next year, he became Vice President - General Manager.

Not confining himself to the administrative side of the automotive industry, he worked during World War I with Christian Girl and Col. Glover of the Motor Transport Corps on development of the famous 5-ton Class B Liberty truck for the services.

When United States Motor Truck went out of business in 1925, Morrison joined John J. Kelly in the Kelly Auto Body Co. Since then Morrison has been designing and producing custom built bodies, particularly insulated and refigerated bodies.

Morrison's memories of SAE meetings date back to the early twenties when he and E. C. Shumard attended SAE Annual Meetings together at the old Algonquin Hotel in Detroit and the meetings held at Indianapolis during race week.

- Harold B. Frye



## SECTION NEWS

CONTINUED FROM PAGE 83

NORTHERN CALIFORNIA Section members were told on June 23 that although from a rancher's viewpoint the 'best' fuel for his light plane might be automotive fuel because of its availability, it is not good fuel for the airplane's fuel system.

In presenting the results of their study of light aircraft fuel systems, R. A. Coit, L. M. Whitney, F. G. Bollo, and A. G. Cattaneo of Shell Development Co. reported that if automotive fuels are used with either gravity feed or diaphragm pump systems, vapor lock will occur well within the range of practical operating conditions.

They found that 7-psi RVP aviation fuels can be used safely under all practical conditions in a properly designed gravity feed fuel system, but that diaphragm fuel pump systems are marginal

At Northern California's May 26 meeting, Fred Lautzenhiser of International Harvester Co., told members that the wise purchaser of large trucks will request more data than just specifications and prices from the truck salesman. To find the best truck for the job, the purchaser needs information on

- Load distribution layout
- Legality of size and weight
- Performance ability
- Estimated operation costs
- Service facilities
- Availability of replacement parts
- Appearance
- Delivery date

Closer clearances, higher temperatures, and higher speeds in modern equipment make it more complicated, yet more important, to select the right lubricant, Carl W. Georgi of Quaker State Oil Refining Corp. told the CENTRAL ILLINOIS Section on April 26.

Present-day greases, he explained, are made of fluid lubricating oils absolved in soap-base additives. Where good water emulsification properties are required but temperatures are not high, calcium- and aluminum-base greases are good.

Where greases must stand high temperatures but water emulsification quality is not important, sodium-base greases excell. Some new sodium- and lithium-base greases are both resistant to water and able to withstand high temperatures, making them all-purpose greases, he said.

At SOUTHERN CALIFORNIA Section, 180 took part in Technical Chairman J. J. Robson's 20-minute panel discussions devoted to passenger cars on May 20. John P. Bond reported that use of aircraft fittings and attention in design to closer tolerances is producing more continuous runs with fewer failure in the 180- to 275-cu in. displacement classes of racing cars.

P. W. Drew praised the new low pressure tires as having faster turning speed through better traction, saving 5% in fuel, making less road noise, and improving appearance. E. Lynn Ballagh outlined the operational sequence of the Buick Dynaflow transmission, pointing out the differences between torque converters and hydraulic drive systems.

"Nothing new under the sun" was the theme of Prof. Dean Fales' talk before the M.I.T. Student Branch on May 18. Prof. Fales, an M.I.T. staff member, recounted the history of the automobile, beginning with a French steamer of 1760 and continuing through the car of today.

He pointed out examples of developments such as fluid and magnetic clutches and the opposed-piston engine that were first used 30 or 40 years ago, yet are now considered new.

## DYNAMIC LOADS

CONTINUED FROM PAGE 72

with respect to the ground under road test conditions cannot be easily measured. These accelerations measured with the strain gage pickup equipment during the drop test are compared with accelerations taken during a road test. (Paper "Determination of

Dynamic Loads in Coach Structures," was presented at SAE National Passenger Car and Production Meeting, Detroit, March 4, 1948. It will be printed in full in SAE Quarterly Transactions. This paper is also available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Outlines Ways To End Paradox of Airlines

Based on speech by

L. T. COHU*

Trans World Airline

AIRLINE management, suppliers, government, and airline employees share the responsibility for checking the paradox of the airlines: that although the airlines of the United States are carrying more passengers and cargo and doing it more efficiently, they are losing more money than ever before. This was the situation in 1947, and figures for the early months of 1948 indicate that the losses may continue unless airline problems are soon solved.

The airlines can help themselves considerably by cooling their competitive fervor. They can combine efforts in market research and in research and development of facilities and equipment. At medium and small cities, they can pool airport services. At large cities, they can pool maintenance and overhaul of engines, instruments, and accessories. And everywhere, they can consolidate downtown ticket offices.

The airlines can cooperate in standardizing accessories, systems, cockpit arrangements, loading devices, and other equipment. Individuality in these items is a luxury the airlines cannot afford.

Instead of pressing for duplication of route awards and facilities for extending through carrier service where additional service is uneconomic, the airlines can coordinate their schedules and interchange equipment. Plans for future expansion must be based on realistic estimates of demand and costs.

Manufacturers who supply airlines can give immediate help by speeding supplies of replacement parts - some of which are scarce even three years after V-J Day. For example, lack of a particular type of bushing has been forcing overhaul shops to cannibalize spare engines.

Airplane manufacturers can give long-range help by cooperating with airlines to make structural and aerodynamic design compatible with simple and dependable accessory and system design.

The cost of complexity is obvious from TWA's experience with DC-4's - estimated to be nearly 2½ times as complex as the DC-3 - and Constellations - over 1½ times as complex as the DC-4. During the year 1946 alone, the cost of introducing these new planes was more than \$8,000,000, in addition to the capital cost of the equipment and spare parts. Besides, grounding of the Constellations cost TWA about another \$7,000,000.

Government can contribute most to sound airlines by making sure that its budgetary and monetary policies do not unduly disrupt the price level. Spiralling of prices robs the fruits of increased efficiency. The airlines can not pass along to passengers and shippers much of the rise in cost of labor and materials because competition among airlines and between airlines and surface carriers is so intense.

Basic government policy dealing with the economic and safety regulations of the airlines, as this policy is expressed in acts of Congress, needs very little overhaul. What is needed is the removal of the chaos and the inconsistencies in *interpretation* of the policies set forth by the Civil Aeronautics Act of 1938. The Civil Aeronautics Board should recognize that:

1. Excessive competition is not necessary in a business so closely regulated as the airline industry.

2. A master plan for route development must be drawn if the chaos and expense of unduly duplicated services are to be avoided.

3. The national defense importance of the airlines and the expenses of their developmental period require a mail rate high enough to cover proper costs and occasionally a special allowance to cover exceptional costs forced on the airlines through no fault of their own.

*Present connection: Consolidated Vultee Aircraft Corp.

4. Decisions in the public interest do not require that each city should immediately be given a feeder line route whether it can be supported or not, or that each city asking for one-carrier service should be given it if by so doing an unsound airline system would result.

5. Certain routes, particularly in the international field, having been granted primarily as a matter of international policy, should be given special financial support by the government.

Government policy with respect to airline labor leaves much to be desired by airline management. The Taft-Hartley Law does not apply to the airlines. Instead they still operate under a Railroad Labor Act which does not particularly suit the airline business.

Labor itself must realize that its monetary rewards and economic security depend upon the success of the airline enterprise. Labor leaders need not operate on the premise that an occasional strike is a good thing to keep management in line and labor union dues paid. Everyone loses in a strike. Airlines must lay their financial facts on the table for their employees to see, so that they can discover for themselves that low cost production of airline service means high wages and steady employment. (Dinner speech was presented at SAE National Aeronautic Meeting, April 15, 1948. This paper is available in full in mimeographed form from SAE Special Publications Department. Price: 25¢ to members. 50¢ to nonmembers.)

## One Stress Prescribed In Disc Design Method

Digest of paper

By C. M. McDOWELL

Packard Motor Car Co.

BY applying Stodola's equation for the compatibility of centrifugal stresses and Timoshenko's equation of equilibrium for a particle in a disc, it is possible to design a disc for which either the radial or the tangential stress distribution along the radius is prescribed for a given rpm.

Of course, the prescribed stress distribution must be realistic. It must meet boundary conditions, as well as not exceed the allowable maximum stress. For example, a radial-stress distribution prescribed for a bored disc not pressed onto the shaft must be zero at the bore and must correspond to average blade pull at the rim.

### FORMULA GIVES SECOND STRESS

Once the distribution of one of the two stresses along the radius has been prescribed, the other stress is determined from the compatibility formula. Since there are no shear stresses and axial stresses can be neglected, the equation becomes a first-order linear differential equation of quite simple form. The constant of integration can be used to fix one boundary condition for the stress distribution which is being sought.

Solution of the compatibility equation provides the disc designer with a compatible pair of stress curves. To obtain the disc outline, he must substitute the stress values in the Timoshenko equation for the equilibrium of a particle, which involves the disc thickness.

### TERMS EVALUATED GRAPHICALLY

The easiest way to solve this differential equation is to sort out the terms which will not integrate as logarithms and evaluate them graphically. Solution of the equation for points along the radius will give the required thickness at each point.

This method does not account for thermal stresses - although it might be possible to extend the method to include them for turbine disc design. Until there is more data on temperature distribution inside turbine discs, it may be wise to account for thermal stresses by keeping their effect in mind when deciding on the centrifugal stress curves to be used.

(Paper "Prescribed-Centrifugal-Stress Design of Rotating Discs," was presented at SAE Annual Meeting, Detroit, Jan. 14, 1948. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Metering Simplified In Fuel-Injection Pumps

Based on paper by


G. M. Lange

and C. W. Van Overbeke

Ex-Cell-O Corp.


(This paper will be printed in full in SAE Quarterly Transactions.)

IN an effort to provide fuel injection equipment at lower cost and to simplify control of fuel metering, Ex-Cell-O Corp. has developed a single-plunger intake-metering pump, suitable for manifold or cylinder injection into spark-ignited automotive engines.

The injection pump consists of three principal parts:

1. Fuel supply pump
2. Fuel metering valve
3. Pumping and distributing plunger

As Fig. 1 shows, fuel from the fuel tank is pumped by the supply pump into a reservoir. The fuel metering valve controls the discharge of fuel from the reservoir into the line leading to the plunger.

The valve is a fuel throttle connected to the air throttle through a linkage calibrated to provide the proper amount of fuel for the corresponding airflow over the operating range of the engine.

The supply pump delivers to the reservoir about twice as much fuel as the engine requires. The excess, prevented from reaching the plunger by the fuel metering valve, enters a line returning from the reservoir to the fuel tank. An orifice installed in the return line is set so that at full engine speed the supply pump develops about 30 psi pressure in the reservoir.

The pumping and distributing plunger is driven off the pump drive gear at a 2-to-1 reduction, so that the plunger revolves at half engine speed. The pump shown in Fig. 1 is designed for a 4-cyl engine and has a cam for each

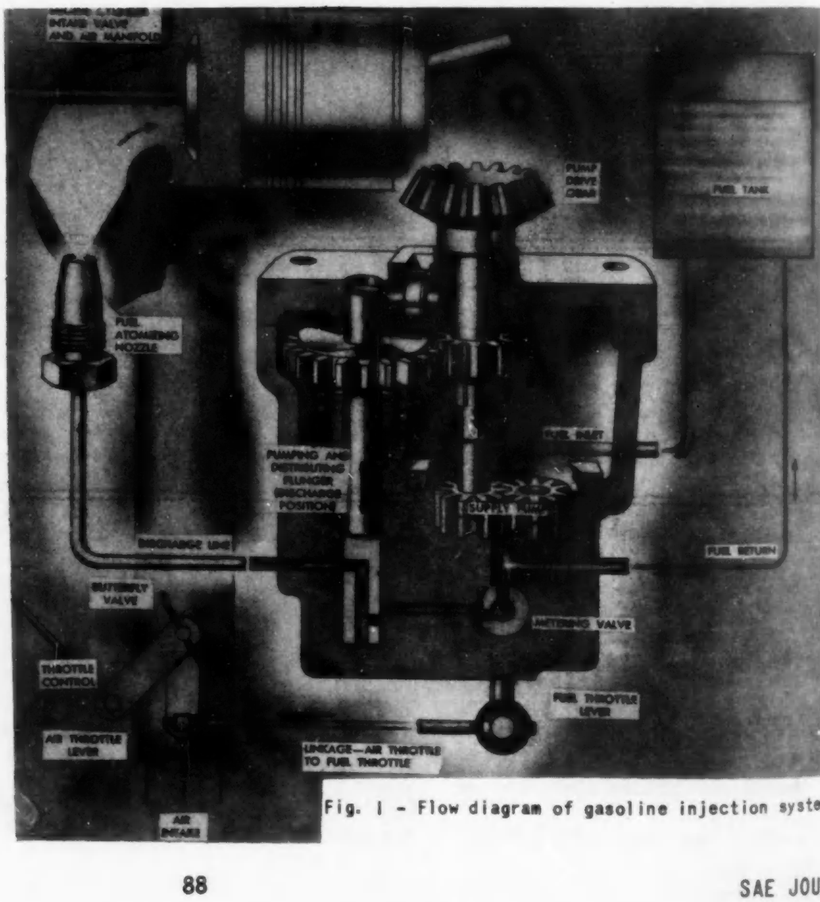



Fig. 1 - Flow diagram of gasoline injection system

cylinder. The cam face is held against a roller in the pump base by a spring. The plunger makes four strokes during each revolution. On the up stroke, fuel enters the plunger reservoir during the time the intake ports in the plunger are in registry with intake ports in the plunger sleeve. The sleeve ports admit fuel ducted from the metering valve.

As the plunger reaches the upper end of its stroke, revolution of the plunger takes the intake ports out of registry. As the plunger starts on the down stroke, the plunger discharge outlet comes into registry with an outlet in the plunger sleeve, and the metered quantity of fuel discharges into a fuel line which conveys the metered fuel to an atomizing nozzle located in the manifold, cylinder head, or cylinder head intake port. (Paper "Fuel Injection for Spark Ignited Automotive Engines," was presented at SAE National Transportation Meeting, Philadelphia, March 31, 1948. This paper is available in full in mimeographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

## Find Fits, Finishes For Engines Differ

Based on paper by

AUGUST SUNNEN, JR.

Sunnen Products Co.

ENGINE manufacturers differ in their recommended smoothness of cylinder wall finish and in specified clearance between piston pin bosses and the pin for reconditioning engines, according to a survey of leaders in the field.

Finish recommendations varied from 4 to 8 micro-inches RMS for a car engine to 20 to 30 micro-inches RMS for a truck engine. We feel a cylinder wall finish slightly below 20 micro-inches is close to the ideal. The way to get this is with a 280-grit silicon carbide stone, used with honing lubricant, after rough honing or boring.

There are two reasons for this.

First, a single-cut boring produces a 60 micro-inch finish on the average. Adding a finishing cut drops the average to about 45 micro-inches. Second machining fact of life is that a cut of several thousandths leaves torn and amorphous metal on the cylinder wall. With honing, thousands of abrasive grains bite into the metal instead of only one or two cutters. Each grain takes a tiny cut from the wall.

Piston-to-piston-boss tolerances also wandered all over the lot. One manufacturer said pins must be selectively fitted to give from 0.0002 to 0.0005-in. clearance. Another, on a 7-in. diameter pin and 16 1/2-in. diameter piston, allows 0.002 to 0.003 in. running clearance between pin and pin boss. Clearance in the rod is from 0.005 to 0.007 in.

Comparable clearances on a 1-in. pin would run about 0.003 to 0.004 in within the piston and 0.007 to 0.001 in. in the rod.

Still a third manufacturer never recommends a definite clearance. This company specifies a finger-fit push at 70 deg. The pin must hold its weight in the hole and the fit should be made without any oil.

Old-fashioned methods of fitting to a "feel," such as this prescribed finger-fit, is not the best way of doing it. "Feel" fits depend on surface finish in the hole as well as straightness and roundness. A multi-peaked rough or uneven surface can't do the job of a full-contact bearing surface in a straight, round hole, with definitely-controlled oil clearance. High spots quickly wear down and the clearance may soon exceed desirable limits.

Accurately-gaged pin holes together with pins fitted to a specific clearance is the only way to assure good fits. (Paper "Fits and Finishes," was presented at SAE St. Louis Section, Sept. 9, 1948. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)



## About SAE Members

CONTINUED FROM PAGE 81

W. LAURENCE LE PAGE has been appointed vice-president in charge of a newly created Engineering Department of the Adrian Bauer Advertising Agency, Inc., Philadelphia. This department will specialize in an engineering approach to sales and advertising problems.

R. F. GAGG, president of Air Associates, Inc., manufacturers and distributors of aviation equipment and supplies, has announced the sale of its Los Angeles plant to the Parker Appliance Co. of Cleveland, Ohio. Air Associates will continue to maintain its Los Angeles Branch with a complete service staff and warehouse stock to serve aviation on the West Coast.

DR. GUSTAV EGLOFF, director of research, Universal Oil Products Co., has been reelected

president of the Chicago Technical Societies Council.

NOEL URQUHART is now manager of mechanical engineering, Engineering Products Department, R.C.A. Victor Division in Camden, N. J.

LESLIE B. HEYWOOD has been transferred from Spokane to the Portland, Oreg. office of Consolidated Freightways. His new position is inspector of equipment, and he has been with this company for over 12 years. Heywood is on the Nominating Committee of the SAE Spokane Intermountain Section.

## New Members Qualified

These applicants qualified for admission to the Society between June 10, 1948 and July 10, 1948. Grades of membership are: (M) Member; (A) Associates; (J) Junior; (Aff.) Affiliates; (SM) Service Members (FM) Foreign Member.

Baltimore Section: Myron S. Gordon (SM), Joseph John Gouza (J), John Clifford Martinka (A), F.J. Smith (A), John W. Thompson (J).

British Columbia Group: Elliott G. Barber (A), John Malcolm Billingsley (A), Nelson Howard Charlton (A), Thomas L. Coulthard (M), Clarence C. McAllister (A).

Buffalo Section: Felix John Grycel, Jr. (J), Damon L. Wescott (M).

Canadian Section: John Crawford Annesley (A), Robert M. Foote (A), A. Roy Jupp (J), John D. Vicary (J).

Central Illinois Section: Wayne Lasky (M).

Chicago Section: C.O. Benson (A), Charles Curtis Berckhemer (J), Oscar T. Ericson (M), Robert W. Helbig (A), E. Clem Jensen (J), William O. Johnson (A), Edward Charles Levit (J), John R. McGuire (J), Joseph Michelini (A), Kenneth Holston Myers (A), Ray C. Nelson (A), Harvey J. Rowe (A), David C. Stukey (M), Thomas E. Sullivan (M), Sanford B. Wanner (A).

Cleveland Section: James Elmo Farmer (SM), Roy S. Godbey (A), Matthew C. Kuepfer (M), Edward T. Kump (M), John E. Martin (A), George E. Meese (M), Arch R. Miller (M), George Boswell Moseley, Jr. (A), Lloyd Jackson Moulton (J), Millard A. Rhoads (M), Elbert S. Rowland (M), Thomas C. Spase (J), William H. Thomas, Jr. (A), John A. Vitkovits (J), Carl W. Weesner (M).

Colorado Group: H. D. Lang (A), Allan P. Shelly (M).

Dayton Section: Richard McKinney Allison (A), Lamar T. Cox (A), Darius S. Flinn (J), Robert William Huller (A), William A. McDorman (J), Robert H. Semenoff (J).

Detroit Section: Leonard E. Adler (J), James Colbert Baker (A), Albin John Burkman (M), E. J. Cloutier, Jr. (A), Claude A. Crusoe (A), Harry Joseph Doyle (A), Burke M. Hyde, Jr. (J), Thor S. Johnson (A), Hart M. King (J), Donald Herman Koch (A), N. Krishnaswami (A), James M. Mason,

Jr. (J), Charles C. Maynard (J), Richard J. McCafferty (M), Richard R. Moore (J), Harold T. Niles (J), Frank Nogar, Jr. (J), Robert Campbell Pascoe (J), Joe S. Rains (J), Ralph Redmond (A), George W. Roberts (J), Cornelius J. Van Halteren (J), J. E. Vollmer (A), Albert Vos (A), Frederick A. Weihe, Jr. (M).

Hawaii Section: Charles R. Baptiste (A), Harvey P. Dawrs (M), Harold J. Hutchins (SM), Jack Chrisitan Latte (A), Lloyd Lowery (A), Kenneth D. McNicoll (A), Thomas E. Miller (A), Robert William Munroe (A).

Indiana Section: Carl F. Lauenstein (M), George S. Myers (M), Paul L. Schneider (M).

Metropolitan Section: William W. Buckley (J), John Henry Crowder, Jr. (J), Donald A. Diehl (A), William Dzus (M), Charles C. Faroni (M), John R. Flannery (A), Donald A. Howes (M), John Sleater Jaquith (J), Ben Karp (J), George F. Marshall (A), R. J. Masiello (J), Ralph T. Millet (J), Nicholas Leonard Paternoster (J), Seymour J. Raymond (J), Henry Scharf (J).

Mid-Continent Section: Claude M. Murray, Jr. (J), Randall A. Sanger (J).

Milwaukee Section: Paul F. Allmendinger (J), Frank L. Harris, Jr. (J), Thomas Evander White (J).

Mohawk-Hudson Group: Dean L. Fisher (M), C. Eugene Lopez (A).

New England Section: C. Norman Fay (A), Joseph Nunes (A).

Northern California Section: Fred E. Greger (A), James A. McAdams (M), Robert W. Roth (M), John Torik (A), Oliver Clare Whitaker (A).

Northwest Section: Ralph Clement Keast (A), Theodore Charles Lash (A), William C. Tarbet, Jr. (J).

Oregon Section: Louis S. Kuhn (A).

Philadelphia Section: Victor M. Mantz (M), Orian Samuel Reasor, Jr. (J), F. Thomas Snyder (J).

Pittsburgh Section: Milton R. Rearick (J).

Salt Lake Group: M.H. Miller (A).

San Diego Section: Harvey Frederick Gerwig (M).

Southern California Section: Richard Edgar Jenkins (M), Ernest C. McAfee, Jr. (J), LeRoy Mylander (A), Harry Pappas, Jr. (J), Harry C. Powell (M).

Southern New England Section: William F. Loomis (A).

Spokane Intermountain Section: Cecil Phipps (A).

Syracuse Section: Eibe W. Deck (M).

Texas Section: Pete M. Curray (A).

Virginia Section: Patrick E. Garner (M), Frederick Tracy Morse (M), Harry A. Patterson (A).

Washington Section: A. R. Goode (A), James H. Horton (SM).

Outside Section Territory: William A. Dobbs (A), Robert C. Forman

(J), Louis H. Hyneman (A), George Ernie Murray (A), Vernon S. Peterson (A), John P. Smeekens (J), Harry J. Sprecken, Jr. (A), Edwin Williams (A).

Foreign: Sobhi Ahmed Ali (J), England; W. Leland Archer (FM), P.I.; Capt. Eric Anstee Beecroft (FM), England; Hartley Melvin Chaplin (FM), Australia; Otto Karl Christoph (A), So. Amer.; Africa; Mincho Alfredo Dalmau-Pichardo (A), West Indies; Peter Victor Dunn, (J), So. Africa; Victor Dunn, (J), So. Africa; George Charles Dutton (FM), England; Geoffrey Edwards (FM), England; Edgar George Gray (A), England; V. Krishnaswami (J), India; Tor Axel Odman (FM), Sweden; Edward Victor Paterson (FM), England; Nemali Ramamurthi (FM), India; Jesus B. Rendon (A), Mexico; John Harold Weaving (FM), England.

## Applications Received

The applications for membership received between June 10, 1948 and July 10, 1948 are listed below.

Baltimore Section: Robertson W. Wilhelm.

British Columbia Group: Harry Raymond Howse.

Buffalo Section: Francis J. Mambretti, Daniel F. O'Donnell.

Canadian Section: Z. M. Ferley, James William Minton, Frank Charles Patterson, Harold Christie Purdy, Arthur A. Scarlett, J. S. Walker.

Central Illinois Section: Dale Leroy Richardson.

Chicago Section: Edwin Edward Dato, Michael Joseph Dudas, Ralph Summerfield, Omer William Swaney, Jr.

Cleveland Section: Frank M. Allen, William L. Hamilton, Alfred M. Hastert, Niles A. Huggler, Frank E. Rom, William C. Sanker, Robert H. Shenk, S. Blackwell Taylor, Marius Van Ramshorst, Donald P. Williams, Frederick D. Wyss.

Colorado Group: Francis E. Raglin.

Dayton Section: Robert E. Harris.

Detroit Section: Clay Patrick Bedford, Charles J. Benner, John J. Bush, Edward M. Eberhart, Jr., Charles R. Goodyear, William Hock, W. Philip Holcombe, Shiba Pada Hore, Herbert Russell Keesy, George A. Kendro, Chester A. Kus, Harry E. Miller, Jr., Earl L. Morrison, H. A. Oestreich, Turgut Oydam, Albert O. Roberts, Jr., Fay A. Roepcke, Lawrence I. Ruby, George C. Shawley, A. D. Wagner, Paul D. Wright.

Hawaii Section: Burley G. Barton, Lester J. Howard, Franklin Carl Leensvaart.

Indiana Section: Jerome Collins, William A. Flumerfelt, William Mack Groover, Ralph M. Lehman.

Kansas City Section: Clark S. Armstrong.

Metropolitan Section: Arthur S. Athens, John H. Boyle , Harold Burg, Franklin M. Cohn, Mervin E. Conn, Jack Ellis Cox, Irwin Haupt, Seymour Charles Himmel, Arthur Kaplan, William W. McClintock, William Gethin Owen, George Sonnermann, Henry Albert Weber, Charles Whol.

Mid-Continent Section: Glenn A. Carlson, Philip S. Donnell, Duane Elvin Marquis, Clarence L. Sterling.

Milwaukee Section: Rudolf Martin Hempel, Vet. V. Homes, Nicholas F. Ledanski, Alfred M. Morrow.

New England Section: Lawrence W. Kelly.

Northwest Section: Homer W. Keith.

Northern California Section: Carrol W. Frazier, Gustavus Simmons Miller, Jr.

Northern New England Section: Tao-Wen Ma.

Philadelphia Section: Edward Hamilton Calkins, Jr., Vytautas S. Mosinskis, Charles S. Vanderblue, Wilbur F. Wilhelm, Jr.,

Pittsburgh Section: W. L. Kann.

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